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SREDOZEMSKI MORSKI PSI

SQUALI MEDITERRANEI

MEDITERRANEAN SHARKS

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OBSERVATIONS ON THE THRESHER SHARK, *ALOPIAS VULPINUS* (CHONDRICHTHYES: ALOPIIDAE) FROM THE COAST OF ALGERIA (SOUTHWESTERN MEDITERRANEAN SEA)

Farid HEMIDA
École Nationale Supérieure des Sciences de la Mer et de l'Aménagement du Littoral (ENSSMAL), BP 19, Bois des Cars, 16320 Dely Ibrahim, Algiers, Algeria

Christian REYNAUD
Laboratoire Interdisciplinaire en Didactique, Education et Formation, Université de Montpellier,
2, place Marcel Godechot, B.P. 4152, 34092 Montpellier cedex 5, France

Christian CAPAPÉ
Laboratoire d'Ichtyologie, Université de Montpellier, 34095 Montpellier cedex 5, France
e-mail: christian.capape@umontpellier.fr

ABSTRACT

Between 1996 and 2002, 194 specimens of thresher shark, Alopias vulpinus, *were sampled from the Algerian coast. Males (102 specimens) did not significantly outnumber females (92 specimens). The collected specimens ranged between 49 and 249 cm in standard length and weighed between 14 and 150 kg. Since 2002, captures of* A. vulpinus *have remained relatively rare throughout the Algerian coast and this phenomenon could indicate a decline of the species' occurrence in this area and probably in the entire Mediterranean.*

Key words: Alopiidae, *Alopias vulpinus*, Maghrebin shore, growth parameters, migrations

OSSERVAZIONI SULLO SQUALO VOLPE, *ALOPIAS VULPINUS* (CHONDRICHTHYES: ALOPIIDAE) DALLA COSTA DELL'ALGERIA (MEDITERRANEO SUD-OCCIDENTALE)

SINTESI

Tra il 1996 e il 2002, 194 esemplari di squalo volpe, Alopias vulpinus*, sono stati catturati lungo la costa algerina. I maschi (102 esemplari) non erano significativamente più numerosi delle femmine (92 esemplari). Gli esemplari catturati variavano tra i 49 e i 249 cm di lunghezza standard e pesavano tra i 14 e i 150 kg. Dal 2002, le catture di* A. vulpinus *sono rimaste relativamente rare lungo tutta la costa algerina e questo fenomeno potrebbe indicare un declino della presenza della specie in quest'area e probabilmente in tutto il Mediterraneo.*

Parole chiave: Alopiidae, *Alopias vulpinus*, costa magrebina, parametri di crescita, migrazioni

INTRODUCTION

The thresher shark, *Alopias vulpinus* (Bonnaterre, 1788) is an oceanic and coastal species widely distributed in warm oceans and seas (Compagno, 1984). It is recorded in the eastern Atlantic from Norway and the British Isles southward to temperate and tropical Atlantic (Quéro, 1984). The species is known throughout the Mediterranean Sea, but appears to be more abundant in the western than in the eastern basin (Capapé, 1989). *A. vulpinus* occurs off the Maghreb shore, from Morocco (Lloris & Rucabado, 1998), Algeria (Refes *et al.*, 2010) to Tunisia (Rafrafi-Nouira *et al.*, 2019). Rare occurrences of *A. vulpinus* were also reported from the Marmara and Black Seas (Kabasakal, 1998, 2007).

Regular investigations conducted in collaboration with experienced fishermen have allowed the observation of several specimens of *A. vulpinus* and improved the knowledge of the species. The main purpose of the present paper is to study some biological parameters recorded about the species in order to model its linear growth.

MATERIAL AND METHODS

Observations were carried out from 1996 to 2002 in the great fish market of Algiers (Fig. 1). The captures of *A. vulpinus* occurred throughout both west and east regions of the Algerian coast (Fig. 2). A total of 194 specimens were examined, standard length (SL) or precaudal fin length (PRC) was measured to the nearest centimetre from the tip of the snout to the beginning of caudal fin (Compagno, 1984). Additionally, their eviscerated weights were recorded to the nearest kilogram. Statistical differences were established using a χ^2 test. The test for normality of the sample was performed using the Shapiro-Wilk test, with $p < 0.05$.

Estimation of growth parameters, such as $SL\infty$ and K, is based on size structure analysis performed by the FISAT logistic model. The data related to collection periods were separated into seasons allowing for size frequency polygons based on monthly samples, with size intervals of 13 cm. The mean sizes of males and females were compared using MANOVA test.



Fig. 1: Specimen of *Alopias vulpinus* ***examined at the fish market of Algiers (Algeria).***
Sl. 1: Primerek morske lisice na ribji tržnici v Algiersu (Alžirija).

Tab. 1: Mean standard lengths (SL) according to sex for* Alopias vulpinus *caught in the eastern and western regions of Algerian coast.
Tab. 1: Povprečna standardna dolžina (SL) morskih lisic, ujetih vzdolž zahodne in vzhodne regije alžirske obale, glede na spol.

Sex	Males		Females	
Region	Eastern	Western	Eastern	Western
Mean SL (cm)	118.80	117.94	118.60	133.62
N of specimens	51	51	56	56

Tests for significance ($p < 0.05$) were performed using ANOVA, and statistical differences were established using a χ^2 test (Schwartz, 1983). The relation between SL and EW was used as a complement following Froese *et al.* (2011). This relation, EW = aSL^b, was converted into its linear regression expressed in decimal logarithmic coordinates, and correlations were assessed by least-squares regression as: log EW = log a + b log SL. Significance of constant b differences was assessed against the hypothesis of isometric growth if $b = 3$, positive allometry if $b > 3$, negative allometry if $b < 3$ (Pauly, 1983). In the relationship EW *versus* SL, comparisons of curves for sexes were carried out using ANCOVA. ANOVA and ANCOVA were performed using the STAT VIEW 5.0 logistic model.

RESULTS AND DISCUSSION

Concerning the collected *A. vulpinus*, the Shapiro-Wilk normality was W = 0.95 with $p< 0.011$, which suggests that the present sample came from a normally distributed population. Of the 194 specimens sampled, 102 were males and 92 females, and thus the former did not significantly outnumber the latter (χ^2 c = 0.51 < χ^2 t = 3.84; df = 1). Similar patterns were observed for the eastern region (56 females, 51 males): females did not significantly outnumber males (χ^2 c = 0.91 < χ^2 c = 3.84; df = 1); conversely, in the western region males outnumbered females (36 females, 51 males) but the difference was not significant (χ^2 c = 1.41 < χ^2 t = 3.84; df = 1).

Standard lengths ranged from 49 to 207 cm and from 63 to 229 cm, in males and females, respectively. The eviscerated weights ranged from 5 to 165 kg, and from 4 to 180 kg in males and females, respectively. Standard lengths of the sampled males and females allowed for calculating mean sizes according to sex and region (Tab. 1). When compared by MANOVA test, it appeared that mean sizes of males and females according to the region were not significantly different, with 1.77< F< 2.21, and 0.16 < p< 0.18.

Size frequency polygons during the period 1996–2002, expressed in percentages, were considered for three seasons (Fig. 3). According to the region, size frequency polygons yielded five apparent modes displaying the values presented in Fig. 4. They also exhibited five apparent modes displaying the fol-

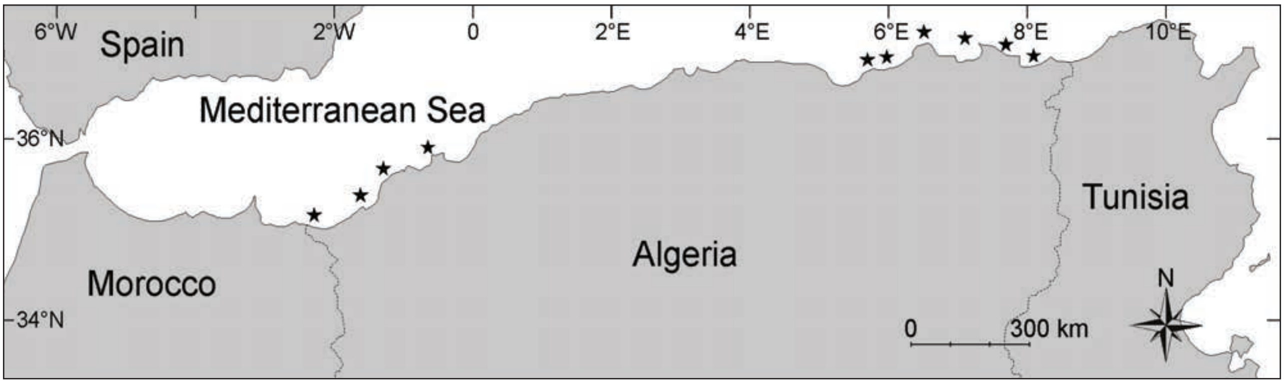


Fig. 2: Map of the Algerian coast indicating the capture sites of* Alopias vulpinus *(stars).
Sl. 2: Zemljevid alžirske obale z označenimi lokalitetami ulova morskih lisic (zvezdice).

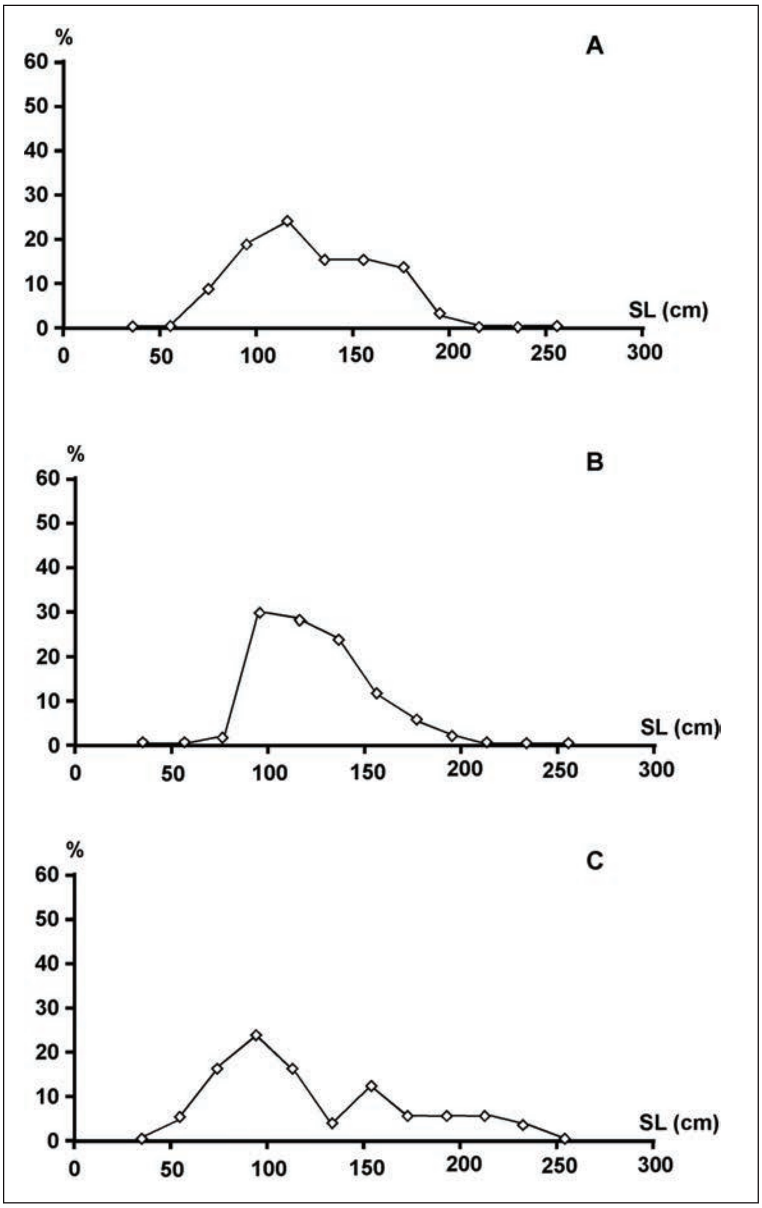


Fig. 3: Size frequency polygons according to seasons reported for** Alopias vulpinus **caught off the Algerian coast. A. Autumn, n = 58. B. Winter, n = 69. C. Spring, n = 54.

Sl. 3: Velikostna porazdelitev poligonov za morske lisice, ujete ob alžirski obali, glede na sezono. A. Jesen, n = 58. B. Zima, n = 69. C. Pomlad, n = 54.

lowing values: 75, 95, 115, 155, and 215 cm (with 95 and 115 repeated twice). The mode 185 was a hidden mode, overlapping other modes more apparent. Additionally, it appeared that the modes moved onto the right side. The minimum SL observed (SL = 49 cm) was less than those recorded by Fischer *et al.* (1987) and Van Grevelynghe (1999), who noted them to be between 114 and 150 cm.

The modal values were grouped following the Petersen method (see Pauly & Moreau, 1997). Age group I comprised specimens from 75 to 115 cm SL, age group II those reaching up to 155 cm SL. Age group III and IV included specimens with an SL over 185 cm and under 215 cm, respectively.

Standard length-at-age data pairs provided by the Petersen method for these four age groups were performed by the FISAT II logistic-model calculating the parameters of the Von Bertalanffy growth equation (see Gayanilo Jr *et al.*, 1985); the equation applied was $SL = 267.66\ [1 - e^{-0.38\ (t + 0.22)}]$. The value of SL ∞ of 267.66 cm was considerably higher than the observed value of 229 cm, and slightly higher than the SL maximum /0.95 (241.05 cm); such results seem to reflect the reality quite accurately (Goldman *et al.*, 2019).

From the fourth year onward, the growth in females is more important than the growth in males. Males reach the size at first sexual maturity in the third year, females in the fifth year (Compagno, 1984; Goldman *et al.*, 2019).

The relationship between total length (TL) and total mass (TM) did not show significant differences between males and females (F = 0.55, p = 0.46, df = 1). Therefore, males and females were included in the same relationship plotted in Fig. 5 according to the following formula: log EW = -4.72 + 3.01 * log SL; r = 0.97; n = 62. *A. vulpinus* displayed an isometric growth, probably because the species found in this region favourable conditions to grow and reproduce. Additionally, the asymptotic eviscerated weight expressed from the relation $EW = a\ W = a\ SL^b$ was: W¥ = 366.13 kg.

The studied sample provided an opportunity to present some biological data concerning *A. vulpinus*, a species poorly known in the Mediterranean Sea (Louisy, 2002; Quéro *et al.*, 2003). Routine monitoring carried out in the fish markets on the Algerian coast showed a relative abundance of this large shark, which is generally appreciated by local consumers. *A vulpinus* is not targeted in the area but holds an interesting economic value, and such a pattern explains its occurrence in local fish markets. However, since the studied

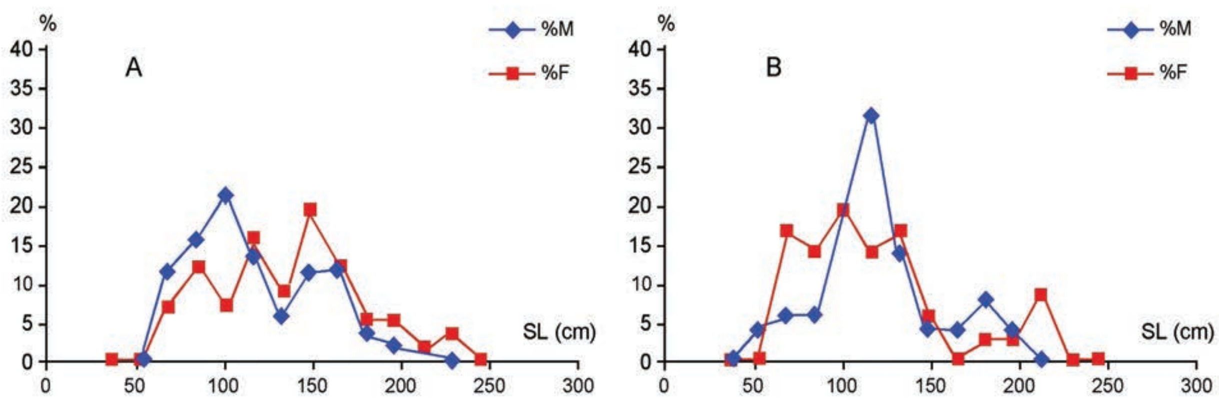


Fig. 4: Size frequency polygons reported for* Alopias vulpinus *caught off the Algerian coast. A. Eastern region, males = 51, females = 56. B. Western region, males = 51, females = 56.
Sl. 4: Velikostna porazdelitev poligonov za morske lisice, ujete ob alžirski obali. A. vzhodna regija, samci = 51, samice = 56. B. Zahodna regija, samci = 51, samice = 56.

period, 1996–2002, captures of *A. vulpinus* have been less abundant and, according to information provided by experienced fishermen, the species has completely disappeared. Such a phenomenon is probably due to overfishing, as corroborated by the opinion of Ferretti *et al.* (2008) who noted a constant decrease of large sharks in the Mediterranean Sea. *A. vulpinus* and other sharks species display *K*-selected characteristics and are object of a drastic decline; their populations are inferred to have reduced by 30–49% over the last seven decades and are assessed to date as VU A2bd (Goldman *et al.,* 2009).

Conversely, recent observations carried out by Rafrafi-Nouira *et al.* (2019) reported captures of several specimens from the northern Tunisian coast. They showed that the species has not totally disappeared from the Maghreb shore, therefore its absence could be explained by migrations into eastern regions, as *A. vulpinus*, like other large shark species, is prone to such large movements (Compagno, 1984; Quéro, 1984). Management of the fishing effort should be conducted to preserve the occurrence of the species in the

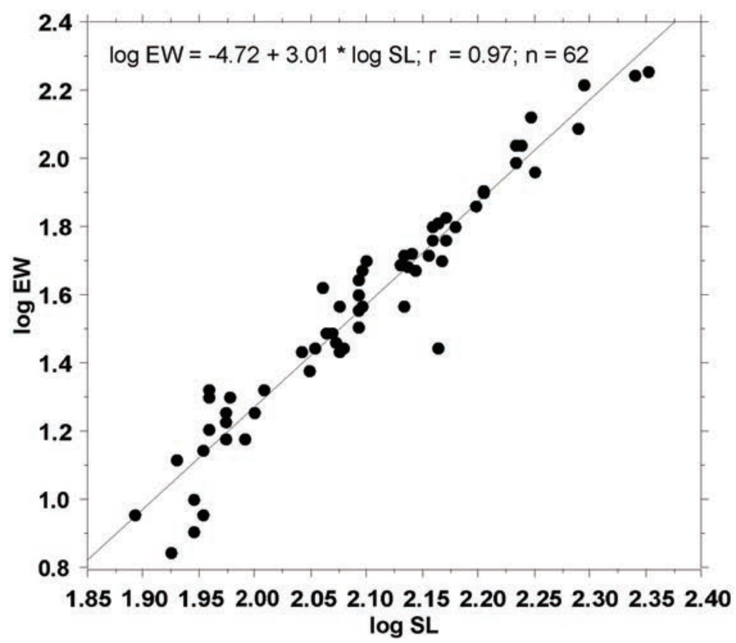


Fig. 5. Eviscerated weight (EW) versus standard length (SL) relationship expressed in logarithmic co-ordinates for* Alopias vulpinus *caught off the Algerian coast.
Sl. 5: Odnos med maso brez drobovja (EW) in standardno dolžino telesa (SL) pri morskih lisicah, ujetih vzdolž alžirske obale, izražen v logaritemskih koordinatah.

Mediterranean Sea. Such opinion is seconded by Ayas *et al*. (2020) for *A. vulpinus* in Turkish Mediterranean waters. They noted that fishery management should be taken into consideration to halt the drastic decline of the species that has been recorded in this area, despite the fact that recently some specimens have been captured and among them a pregnant female carrying developed embryos. The sample used in the present study provides information on growth parameters and could be used further to assess the real status of this species in the Mediterranean Sea.

OPAZOVANJA MORSKIH LISIC, *ALOPIAS VULPINUS* (CHONDRICHTHYES: ALOPIIDAE) OB ALŽIRSKI OBALI (JUGOZAHODNO SREDOZEMSKO MORJE)

Farid HEMIDA
École Nationale Supérieure des Sciences de la Mer et de l'Aménagement du Littoral (ENSSMAL), BP 19, Bois des Cars, 16320 Dely Ibrahim, Algiers, Algeria

Christian REYNAUD
Laboratoire Interdisciplinaire en Didactique, Education et Formation, Université de Montpellier, 2, place Marcel Godechot, B.P. 4152, 34092 Montpellier cedex 5, France

Christian CAPAPÉ
Laboratoire d'Ichtyologie, Université de Montpellier, 34095 Montpellier cedex 5, France
e-mail: christian.capape@umontpellier.fr

POVZETEK

Med leti 1996 in 2002 je bilo ob obali Alžirije ujetih 194 primerkov morske lisice, Alopias vulpinus. *Samcev (102 primerka) ni bilo znatno več od samic (92 primerkov). Primerki so merili med 49 and 249 cm standardne dolžine in so tehtali med 14 in 150 kg. Od leta 2002 so postali ulovi morskih lisic razmeroma redki vzdolž celotne alžirske obale, kar bi lahko odražalo upad populacije na obravnavanem predelu in verjetno tudi na nivoju celotnega Sredozemskega morja.*

Ključne besede: Alopiidae, *Alopias vulpinus*, magrebska obala, rastni parametri, migracije

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NOTES ON SMOOTHBACK ANGEL SHARK, *SQUATINA OCULATA* (SQUATINIFORMES: SQUATINIDAE) CAUGHT IN THE GULF OF ANTALYA

Elif ÖZGÜR ÖZBEK
Turkish Marine Research Foundation (TUDAV), Beykoz, İstanbul, Turkey

Hakan KABASAKAL
Ichthyological Research Society, Tantavi mahallesi, Menteşoğlu caddesi, İdil apt., No: 30, D: 4, TR-34764 Ümraniye, İstanbul, Turkey
e-mail: kabasakal.hakan@gmail.com

ABSTRACT

A total of 15 specimens of Squatina oculata *were incidentally caught in the Aegean and Mediterranean waters of Turkey between 1998 and 2018. The largest individual among them measured 95 cm in TL and 6000 g in TW. On the basis of the examined individuals, the* a *and* b *parameters of* S. oculata *in Turkish waters were found to be 0.003 and 3.27, respectively. The female smoothback angel shark (88 cm TL) caught in spring 2010 aborted 7 embryos following hauling on the deck of the trawler. The length-weight relationship parameters determined in this study for* S. oculata *undoubtedly provide length-weight data only for populations occurring in Turkish waters and are limited, considering the number of specimens studied. However, considering the critically endangered and rare status of* S. oculata*, this information can contribute to filling the current knowledge gap in relation to the species.*

Key words: *Squatina oculata*, Levant Sea, biology, embryo, length-weight relationship

NOTE SULLO SQUADRO PELLE ROSSA, *SQUATINA OCULATA* (SQUATINIFORMES: SQUATINIDAE) CATTURATO NEL GOLFO DI ANTALYA

SINTESI

Un totale di 15 esemplari di Squatina oculata *sono stati catturati accidentalmente nelle acque turche dell'Egeo e del Mediterraneo tra il 1998 e il 2018. L'individuo più grande misurava 95 cm di lughezza totale (TL) e 6000 g di peso totale (TW). In base degli individui esaminati, i parametri* a *e* b *di* S. oculata *nelle acque turche sono risultati essere rispettivamente pari a 0,003 e 3,27. La femmina di squadro pelle rossa (88 cm TL) catturata nella primavera del 2010 ha abortito 7 embrioni dopo essere stata trascinata sul ponte del peschereccio. I parametri del rapporto lunghezza-peso determinati in questo studio per* S. oculata *forniscono senza dubbio dati sulla lunghezza-peso solo per le popolazioni che si trovano nelle acque turche e sono limitati, considerando il numero di esemplari studiati. Tuttavia, considerando che la specie viene considerata rara e minacciata di estinzione, queste informazioni possono contribuire a colmare l'attuale vuoto di conoscenza in relazione alla specie.*

Parole chiave: *Squatina oculata*, mare di Levante, biologia, embrione, rapporto lunghezza-peso

INTRODUCTION

The smoothback angel shark, *Squatina oculata* Bonaparte, 1840, is one of the 3 species of the family Squatinidae occurring in the Mediterranean (Serena, 2005; Giovos *et al.*, 2022). Its distribution range extends throughout the Mediterranean Sea and across the eastern Atlantic Ocean from Morocco to Angola (Serena, 2005). *S. oculata* is a bottom-dwelling shark found in sandy and muddy habitats at depths between 20 and 560 m, and commonly between 50 and 100 m (Serena, 2005). Although the maximum total length determined for this species is 160 cm (Otero *et al.*, 2019), there have been reports of individuals reaching up to 180 cm (Akşıray, 1987).

S. oculata is considered a critically endangered and rare shark species in the Mediterranean Sea (Morey *et al.*, 2019; Otero *et al.*, 2019). Our knowledge of the biology of the smoothback angel shark is mostly based on the results of studies of individuals caught in the western Mediterranean and tropical eastern Atlantic (Capapé *et al.*, 1990, 1999, 2002); published data related to the biology of this species in the eastern Mediterranean are limited, based on studies of sporadic individuals (Ergüden *et al.*, 2019; Yığın *et al.*, 2019). In the present study, authors report on the developing embryos and length-weight relationship of *S. oculata* caught in Turkish waters.

MATERIAL AND METHODS

This study is a sub-study of an extensive bottom-trawl survey carried out between August 2009 and April 2010 on a seasonal basis by the first author, in order to obtain data on the catch composition of commercial trawlers in the Gulf of Antalya, between the depths of 25 and 200 m (Fig. 1). The Gulf of Antalya is located in the north-eastern Levant Basin and is characterised by a high temperature, salinity, and oligotrophy (Kebapçıoğlu *et al.*, 2010). The geographical coordinates of 29 trawling areas at six stations vary between N 36°52'485 and 36°23'000, and E 31°32'322 and 30°29'488. The research was conducted seasonally, both during the "closed" fishing season (August 2009) and during "open" fishing season (November 2009; February 2010 and April 2010) in no-trawl zones as well as open areas. A total of 116 hauls were carried out at depths of 25, 50, 75, 100, 150, and 200 m, at six stations. The duration of each haul was limited to an hour. Specimens of *S. oculata* were caught in trawl hauling and towing at depths between 50 and 100 m.

Species identification was performed based on Serena (2005). The log-transformation formula of Le Cren (1951) was used to establish the length-weight relationship (LWR) of *S. oculata* in Turkish waters, which was based on unpublished data on specimens captured during the trawl expeditions, as well as on length and weight data extracted from the literature (Başusta *et al.*, 1998; Kabasakal & Kabasakal, 2004; Ergüden *et al.*, 2019; Yığın *et al.*, 2019). Although the weight of the smoothback angel shark (75.6 cm TL) mentioned in Başusta *et al.* (1998) was not reported, this information was communicated by the first author of the mentioned publication (Nuri Başusta, *pers. comm.*) After measuring their total lengths (TL, cm) and total weights (TW, g), smoothback angel sharks were released to sea alive as soon as possible, following the best practice procedure for shark bycatch (FAO & ACCOBAMS, 2018).

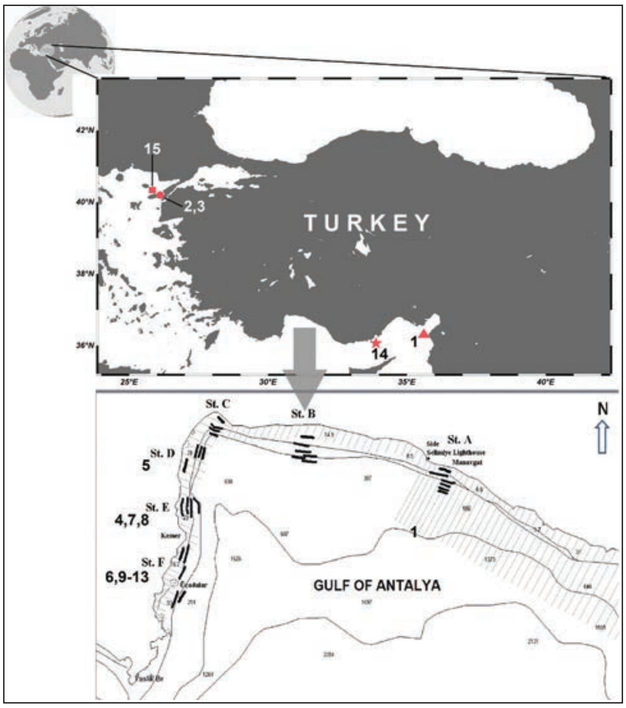


Fig. 1: Maps depicting the capture sites of previously published individuals (above map) and trawled individuals of *Squatina oculata* ***in Turkish waters. In the Gulf of Antalya, individuals of*** *S. oculata* ***(n=10) were caught in trawl hauling at stations D, E, and F. Numbers on the map correspond to those reported in Table 1.***

Sl. 1: Zemljevid z označenimi lokalitetami, kjer so bili doslej ugotovljeni primerki pegastega sklata na podlagi objavljenih zapisov (zgornji zemljevid) in ujeti primerki v turških vodah. V Antalijskem zalivu so bili pegasti sklati (10 primerkov) ujeti na postajah D, E in F. Številke se ujemajo s tistimi v Tabeli 1.

RESULTS

The combined results of the 2009–2010 trawling survey and specimens reported in previous publications (Başusta *et al.*, 1998; Kabasakal & Kabasakal,

Tab. 1: Data on individuals of* Squatina oculata *captured in Turkish waters. Jul: July, Sep: September; Aut: Autumn; Spg: Spring; Wnt: Winter; Nov: November; Mar: March.
Tab. 1: Podatki o primerkih pegastega sklata, ujetih v turških vodah. Okrajšave: Jul: julij, Sep: september; Aut: jesen; Spg: pomlad; Wnt: zima; Nov: November; Mar: Marec.

No	Date	TL (cm)	W (g)	Sex	Depth (m)	Reference
1	1996	75.6	4000	?	60	Başusta *et al.* (1998)
2	Jul 1997	30	180	M	70	Kabasakal & Kabasakal (2004)
3	Sep 1999	95	6000	F	80	Kabasakal & Kabasakal (2004)
4	Aut 2009	80	4500	?	100	Present study
5	Spg 2010	50	850	?	100	Present study
6	Spg 2010	88	5550	F	50	Present study
7	Spg 2010	59	1600	?	50	Present study
8	Spg 2010	52	1000	?	100	Present study
9	Wnt 2010	67	1700	?	50	Present study
10	Wnt 2010	69	1800	?	50	Present study
11	Wnt 2010	66	2000	?	50	Present study
12	Wnt 2010	88	5500	?	50	Present study
13	Wnt 2010	24	71	?	50	Present study
14	4 Nov 2017	72.6	3450	F	65	Ergüden *et al.* (2019)
15	22 Mar 2018	87.5	5536	F	110	Yığın *et al.* (2019)

2004; Ergüden *et al*., 2019; Yığın *et al*., 2019) have revealed that a total of 15 specimens of *Squatina oculata* were incidentally caught in the Aegean and Mediterranean waters of Turkey between 1998 and 2018 (Tab. 1; Fig. 2). The TL and TW of these individuals, the fishing depths, and references of previously reported individuals are shown in Table 1. The largest individual measured 95 cm in TL and 6000 g in TW (TL range 24–95 cm; mean TL = 66.91±20.98 cm; TW range 71–6000 g; mean TW = 2916.8±2117.5 g). Based on the examined individuals, the *a* and *b* parameters of *S. oculata* in Turkish waters were found to be 0.003 and 3.27, respectively. The LWR of *S. oculata* in Turkish waters is shown in Fig. 3.

The female smoothback angel shark (88 cm TL; specimen no. 6; Table 1) caught in spring 2010 aborted 7 embryos following hauling on the deck of the trawler; thus, it could not be determined how many embryos had been in each uterus (Fig. 4). After its length and weight had been measured, the pregnant female was immediately released back into the sea. In this female, symptoms resembling post-release stress such as fluttering on the water surface or sinking to the bottom by remaining motionless were not observed; instead, the individual swam away in a healthy way. It was observed that all 7 embryos had their stomachs filled with yolk and the yolk sac was still unabsorbed (Fig. 4). Therefore, it is clear that the embryos were still at the developing stage.

DISCUSSION AND CONCLUSIONS

According to Tsikliras and Dimarchopoulou (2021), *Squatina oculata* is one of the 46 uncommon chondrichthyan species occurring in the Mediterra-



Fig. 2: Individuals of* Squatina oculata *incidentally caught during 2009–2010 bottom trawl expeditions in the Gulf of Antalya (Photo: E. Özgür Özbek).
Sl. 2: Naključno ujeti primerki pegastega sklata na ribiških odpravah med 2009 in 2010 v Antalijskem zalivu.

nean Sea on which there is a significant knowledge gap in relation to LWR data. Based on the lengths (TL range 29.1–79.5 cm) and weights (TW range 173–3750 g) of 6 smoothback angel sharks, Tsikliras and Dimarchopoulou (2021) calculated the *a* and *b* parameters of *S. oculata* occurring in Greek and Italian waters to be 0.0067 (range 0.0061–0.0076) and 3.04, respectively. Despite the slight differences, the *a* and *b* values in the present study (0.003 and 3.27, respectively) appear comparable to those calculated by Tsikliras and Dimarchopoulou (2021). The differences between these two studies may originate from environmental conditions or interindividual variability due to biological conditions. Since the expected range of $2.5 < b < 3.5$ was confirmed by Froese (2006), the *b* value found in the present study coincides within the safe limits, which is supposed to indicate a tendency towards positive-allometric growth or an increase in relative body thickness of *S. oculata* in Turkish waters.

S. oculata is a lecithotrophic shark with a minimum one-year-long gestation period (Capapé *et al.*, 2002). Studies carried out off the Senegal coast showed that adult females exceeded 89 cm in TL (Capapé *et al.*, 2002). In Tunisian waters, the TL range in subadult females was 75–90 cm, and individuals between 100 and 121 cm TL were considered adults (Capapé *et al.*, 1990). Although the size of the pregnant female in the present study (88 cm TL) was within the limits of subadult females (Capapé *et al.*, 2002) and clearly below the lower limit (100 cm TL) for adults (Capapé *et al.*, 1990), our findings show that pregnant females of *S. oculata* can be shorter than the previously observed size ranges.

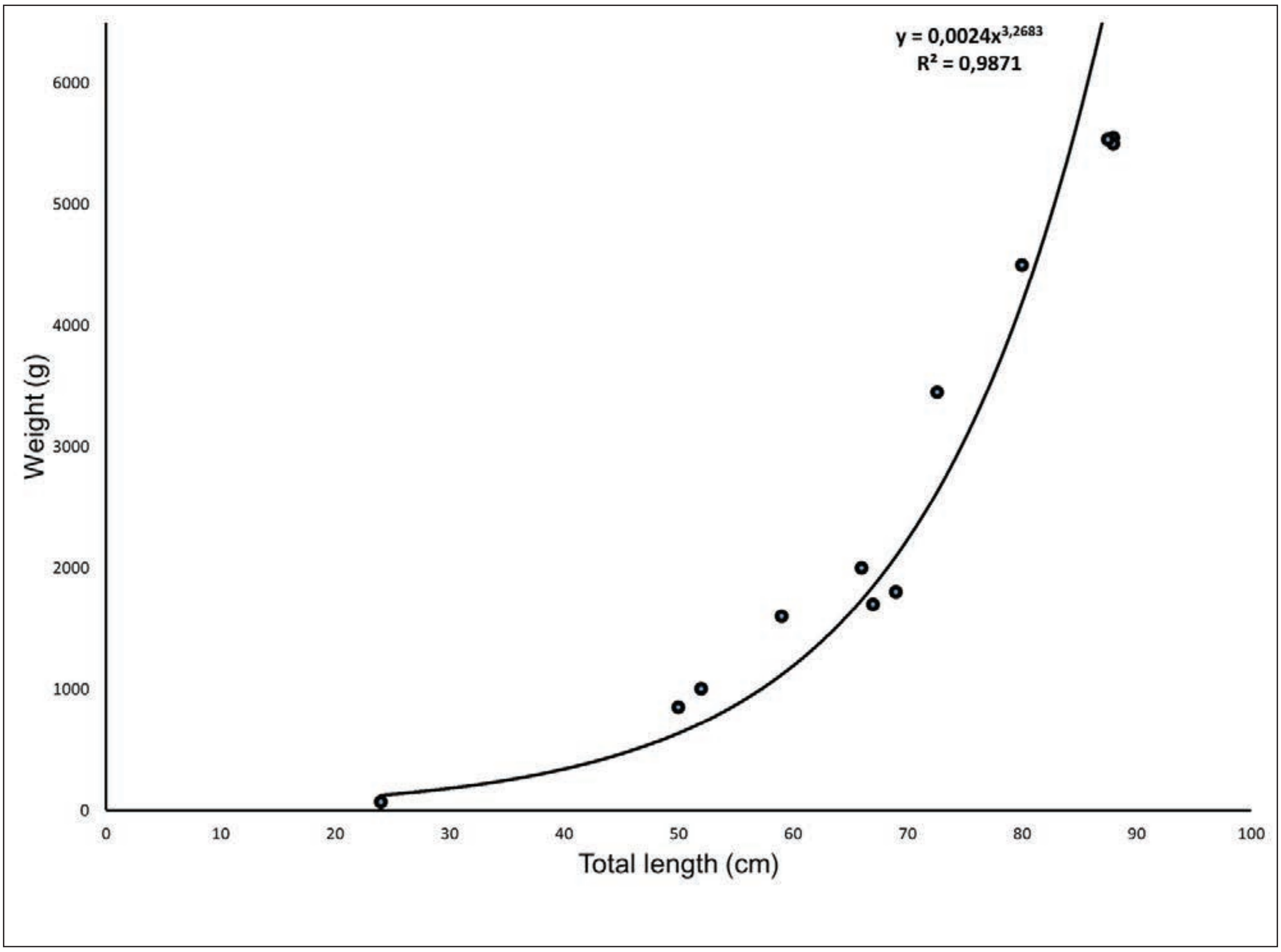


Fig. 3: Length-weight relationship graph of** Squatina oculata **based on individuals caught in Turkish waters (n=15; TL range 24–95 cm; mean TL = 66.91±20.98 cm; TW range 71–6000 g; mean TW = 2916.8±2117.5 g).
Sl. 3: Diagram, ki prikazuje dolžinsko-masni odnos za primerke pegastega sklata v turških vodah (n=15; dolžinski razpon24–95 cm; povprečna dolžina telesa = 66.91±20.98 cm; masni razpon 71–6000 g; povprečna telesna masa = 2916.8±2117.5 g).

Furthermore, Yığın *et al*. (2019) observed a total of 6 symmetrically distributed developing oocytes in a female of *S. oculata* of 87.5 cm TL (specimen no. 15; Table 1), which supports our suggestion that females of smoothback angel shark can mature at smaller size ranges than published.

According to Capapé *et al*. (2002), the size at birth of *S. oculata* is between 225 and 266 mm TL (mean SD = 245.25 ± 11.95), and the weight between 129 and 151 g (mean SD = 142.20 ± 9.33). The TL and TW of the developing embryos (24 cm and 71 g, respectively) examined in the present study were within the range of TL reported by Capapé *et al*. (2002); while the TW was slightly below the lower limit. Considering that the examined embryos were aborted by a female captured during a spring expedition (April 2010), and Capapé *et al*. (2002) states that embryos are practically at the end of their development in February and March, the examined developing embryos would have been born during the upcoming summer of 2010. Capapé *et al.* (2002) also observed fully developed foetuses in females caught from March to June, which supports our suggestion.

All three Mediterranean *Squatina* species (*S. aculeata, S. oculata*, and *S. squatina*) are currently considered to be critically endangered in the Mediterranean (Dulvy *et al*., 2016; Giovos *et al*., 2022). Although all three species are under protection in Turkish waters, it appears that legal measures are not sufficient to defend these critically endangered species. As a result of both historical and current overfishing, *Squatina* populations still tend to decrease significantly throughout the Mediterranean (Dulvy *et al*., 2016). In a recent study on the life history of the common angel shark in Turkish waters, Kabasakal (2021) drew attention to seasonal aggre-



Fig. 4. (A) Developing embryos (n=7; total weight 500 g) aborted by a pregnant *Squatina oculata* ***(88 cm TL; specimen no. 6; Table 1); and (B) ventral view of an embryo, depicting yolk sac and ingested yolk (Photo: E. Özgür Özbek).***
Sl. 4: (A) Razvijajoči se zarodki (n=7; totalna masa 500 g), ki jih je splavila samica pegastega sklata (88 cm telesne dolžine; primerek št. 6; Tabela 1); in (B) ventralni pogled na zarodek prikazuje rumenjakovo vrečo in požrt rumenjak (Foto: E. Özgür Özbek).

gations of *S. squatina* in 5 different regions along the Turkish coast noting that these hot spots lead to a false perception of the species' abundance. Such misunderstanding or misinterpretation of seasonal aggregations of angel sharks in those hotspots may be used by fishermen as a justification for when they capture angel sharks or land incidentally captured individuals (Kabasakal, 2021). Therefore, it is clearly necessary and urgent to map and ban fishing in marine areas where angel sharks are known to aggregate seasonally. The importance of such protected areas for the conservation of *Squatina* species has also been stressed in a recent study by Giovos *et al*. (2022).

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ZAPIS O PEGASTIH SKLATIH, *SQUATINA OCULATA* (SQUATINIFORMES: SQUATINIDAE), UJETIH V ANTALIJSKEM ZALIVU

Elif ÖZGÜR ÖZBEK
Turkish Marine Research Foundation (TUDAV), Beykoz, İstanbul, Turkey

Hakan KABASAKAL
Ichthyological Research Society, Tantavi mahallesi, Menteşoğlu caddesi, İdil apt., No: 30, D: 4, TR-34764 Ümraniye, İstanbul, Turkey
e-mail: kabasakal.hakan@gmail.com

POVZETEK

*Petnajst primerkov pegastega sklata (*Squatina oculata*) je bilo naključno ujetih v egejskih in sredozemskih vodah Turčije med leti 1998 in 2018. Največji med njimi je meril 95 cm v dolžino in tehtal 6000 g. Na podlagi preiskanih primerkov, sta bila koeficienta a in b za pegaste sklate v turških vodah 0,003 in 3,27. Spomladi 2010 ujeta samica pegastega sklata (88 cm telesne dolžine) je na palubi ribiškega plovila splavila 7 zarodkov. Dolžinsko masni odnos nedvomno temelji le na podatkih dolžine in mase le za turške populacije pegastih sklatov, obenem pa vzorec temelji na omejenem številu preiskanih primerkov. Glede na dejstvo, da gre za kritično ogroženo vrsto, ki ima status redke vrste, bodo ti podatki uporabni za zapolnitev vrzeli o poznavanju te vrste.*

Ključne besede: *Squatina oculata*, Levantsko morje, biologija, zarodki, dolžinsko-masni odnos

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UNDERWATER OBSERVATIONS OF THE RARE ANGULAR ROUGHSHARK *OXYNOTUS CENTRINA* (CHONDRICHTHYES: SQUALIDAE) IN THE WATERS OF SANTA TECLA (SICILY, ITALY)

Alessandro PAGANO
Via Duca degli Abruzzi 40, 95127 Catania, Italy
e-mail: alessandro.pagano@tim.it

Alessandro DE MADDALENA
Shark Museum, 26 Forest Hill Road, Simon's Town, 7975 Cape Town, South Africa
e-mail: alessandrodemaddalena@gmail.com

ABSTRACT

Three encounters with the uncommon and elusive angular roughshark, Oxynotus centrina*, are reported from the waters off Santa Tecla, Catania, Italy, in the Western Ionian Sea. The three observations occurred on 11 June 2019, 26 February 2020 and 26 January 2022, between 74 and 84 m depth. The sharks encountered were three different female individuals. Photographs of the sharks were taken on all the encounters.*

Key words: angular roughshark, *Oxynotus centrina*, Sicily, Ionian Sea, Mediterranean Sea

OSSERVAZIONI SUBACQUEE DEL RARO PESCE PORCO *OXYNOTUS CENTRINA* (CHONDRICHTHYES: SQUALIDAE) NELLE ACQUE DI SANTA TECLA (SICILIA, ITALIA)

SINTESI

Vengono riportati tre incontri con il poco comune ed elusivo pesce porco, Oxynotus centrina*, nelle acque di Santa Tecla, a Catania, in Italia, nel Mar Ionio Occidentale. Le tre osservazioni hanno avuto luogo l'11 giugno 2019, il 26 febbraio 2020 e il 26 gennaio 2022, tra i 74 e gli 84 m di profondità. Gli squali incontrati erano tre diversi individui, di lunghezza stimata di 75, 60 e 50 cm rispettivamente, tutti di sesso femminile. La documentazione fotografica è stata raccolta durante tutti gli incontri.*

Parole chiave: pesce porco, *Oxynotus centrina*, Sicilia, Mar Ionio, Mare Mediterraneo

INTRODUCTION

The angular roughshark, *Oxynotus centrina* (Linnaeus, 1758), belongs to the Order Squaliformes and the family Oxynotidae. The morphology of this species includes: no anal fin, broad dorsal fins with first dorsal fin origin over pectoral fin origin, fin spines on both dorsal fins, short pectoral fins, moderately long caudal fin upper lobe and short lower lobe, no caudal fin posterior notch, stout body, ventral ridges, large dermal denticles, short snout, small mouth with enlarged labial parts, large nostrils, large eyes, large spiracles, and five pairs of short gill slits. The coloration of the dorsal surfaces is grey-brown or blackish with a lighter pattern on the lateral part of the head, sides, caudal peduncle and caudal fin; the ventral surfaces are partially lighter. Its size at birth is 21-24 cm and the maximum size is 150 cm. The embryonic development of this species is aplacental viviparous, with unknown gestation and litter size of 7-23 young. It is a benthic species that lives on continental shelves and upper slope, at depths ranging from 50 m to at least 725 m, with nocturnal habits, feeding on bony fishes, small-spotted catshark eggs, crustaceans, and polychaetes (Bigelow & Schroeder, 1948; Bass *et al.*, 1976; Compagno, 1984; De Maddalena *et al.*, 2015).

It is found in the Eastern Atlantic Ocean and its presence throughout the Mediterranean Sea is well documented, despite being an uncommon species in the entire area, and very rare in most sites (Tortonese, 1956; Capapé, 1977; Cadenat & Blache, 1981; Bauchot, 1987; Vanni, 1992; Moreno, 1995; Mizzan, 1994; Barrull *et al.*, 1999; Barrull & Mate, 2001; Barrull & Mate, 2002; Dulvy *et al.*, 2003; Lipej *et al.*, 2004; Kabasakal, 2010; De Maddalena *et al.*, 2015; Kousteni & Megalofonou, 2016; Koehler, 2018; Capapé *et al.*, 2021; Gajić *et al.*, 2021).

Keeping in mind the paucity of observation of live individuals of this species (Kabasakal, 2009), it was considered important to report on recent underwater observations that occurred in the waters of the Western Ionian Sea, off the Eastern Sicilian coast.

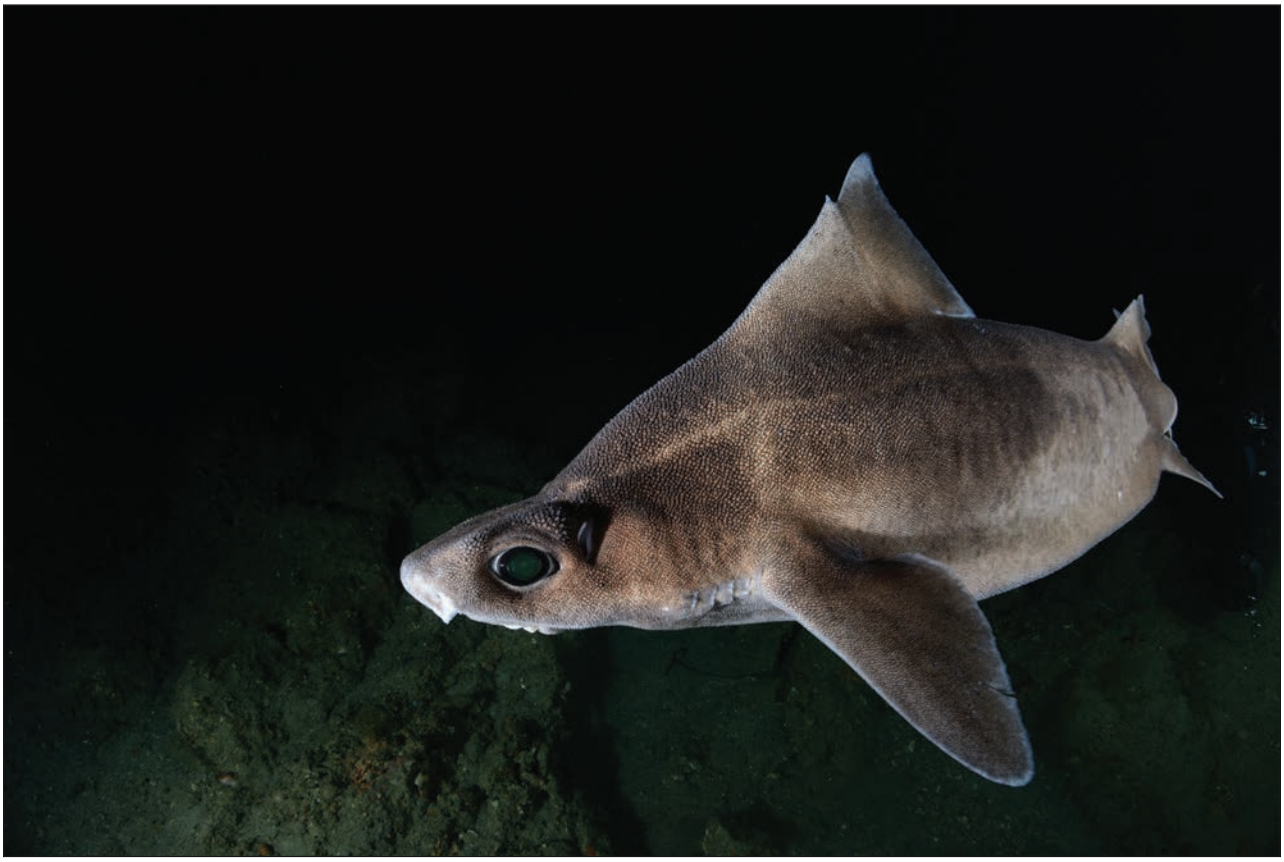


Fig. 1: The estimated 75 cm TL angular roughshark,* Oxynotus centrina*, observed off Santa Tecla, Catania, on the Eastern Coast of Sicily, Italy, on 11 June 2019 at 10:16, at 74 m depth (photo: A. Pagano).
Sl. 1: Približno 75 cm dolga samica morskega prašiča,* Oxynotus centrina*, opažena 11. junija 2019 ob 10:16, na globini 74 m ob Santa Tecli, Catania, na vzhodni obali Sicilije v Italiji (foto: A. Pagano).

Tab. 1: Main details of the three encounters with angular roughsharks, *Oxynotus centrina**, **reported in this article.***
Tab. 1: Glavne podrobnosti o treh srečanjih z morskimi prašiči, *Oxynotus centrina**, **o katerih avtorja poročata v prispevku.***

Date	Location	Depth (m)	Sex	Estimated TL
11 June 2019	Santa Tecla, Catania, Italy	74	F	75 cm
26 February 2020	Santa Tecla, Catania, Italy	84	F	60 cm
26 January 2022	Santa Tecla, Catania, Italy	84	F	50 cm

MATERIAL AND METHODS

The first author experienced three encounters with angular roughsharks while scuba diving with another diver, Eugenio Longo, by Closed Circuit Rebreather in the waters of the Western Ionian Sea, off Santa Tecla, Catania, on the Eastern Coast of Sicily, Italy (latitude: 37.639682105936735 N, longitude: 15.183723565445055 E). The weather conditions were good, with calm sea. The dive site is located 150 m from the shore, where the bottom depth is between 80 and 110 m. The site is a rocky landslide that ends on a sandy bottom. The average temperature of the water was 14°C on all three encounters. The first author dives about 50 times per year on the observation site, with an average of one dive per week.

Sharks were photographed using a Nikon D800 reflex camera with a Tokina 10-17 mm lens for subse-

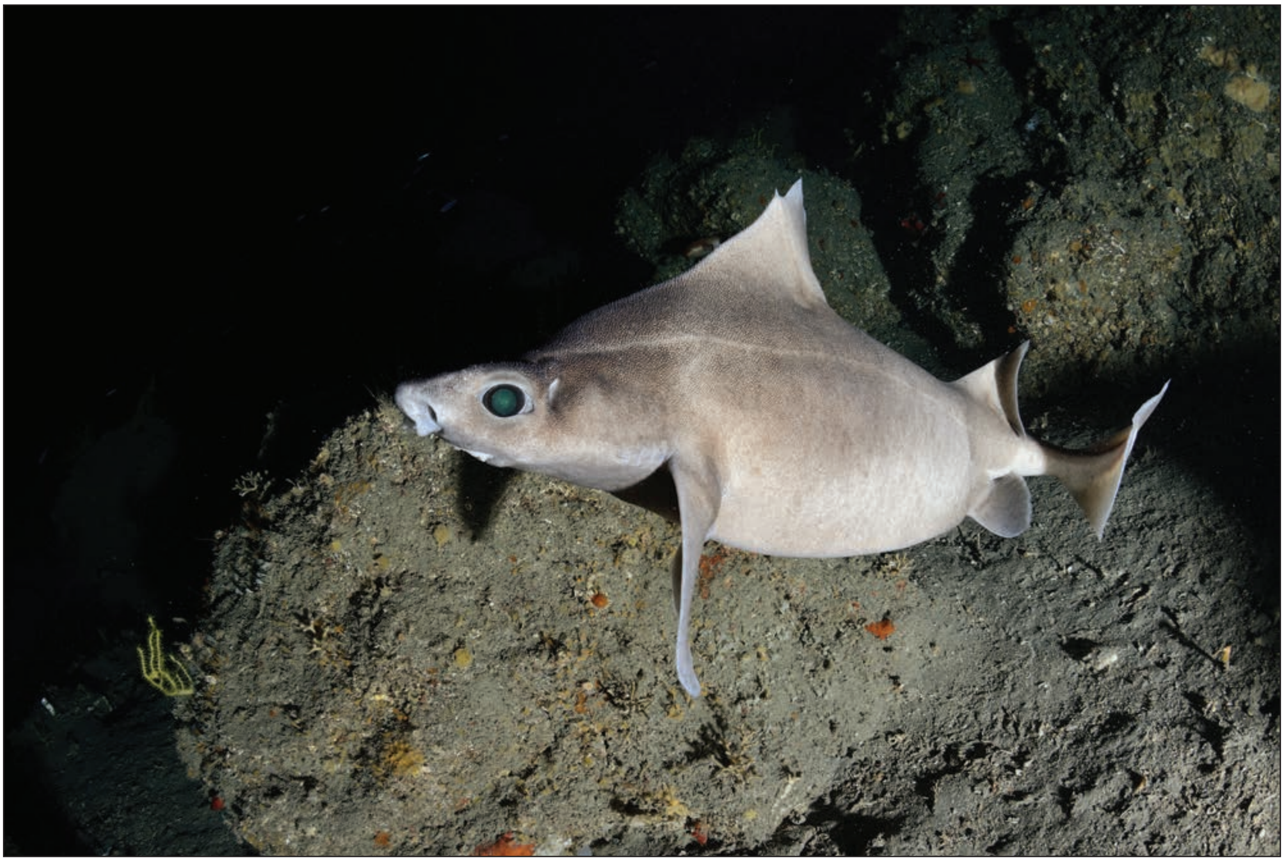


Fig. 2: The estimated 60 cm TL angular roughshark observed on the same site on 26 February 2020 at 10:26, at 84 m depth (photo: A. Pagano).
Sl. 2: Približno 60 cm dolga samica morskega prašiča, *Oxynotus centrina**, **opažena na isti lokaliteti 26. februarja 2020 ob 10:26, na globini 84 m (foto: A. Pagano).***

quent analyses of their morphology and photoidentification of the individuals occurring in the area.

RESULTS AND DISCUSSION

On each encounter an individual female angular roughshark was observed (Tab. 1). The first encounter occurred on the morning of 11 June 2019, at 10:16, when the divers were at 74 m depth and the angular roughsark observed was estimated at 75 cm total length (TL). The second encounter occurred on the morning of 26 February 2020, at 10:26, when the divers were at 84 m depth, only 30 m from the site of the first encounter. This second shark was estimated at 60 cm total length. The third encounter occurred in the morning of 26 January 2022, at 11:26, once again when the divers were at 84 m depth, exactly in the same site of the second encounter. This third individual was estimated at 50 cm total length. Each encounter lasted 10 to 20 minutes.

Other species observed on the three encounters included the swallowtail seaperch, *Anthias anthias* (Linnaeus, 1758), the serpent eel, *Ophisurus serpens* (Linnaeus, 1758), the yellow gorgonian, *Eunicella cavolinii* (Koch, 1887), the small polyped gorgonian, *Paramuricea clavata* (Risso, 1826), and the red coral, *Corallium rubrum* (Linnaeus, 1758).

Based on the shape of the dorsal fins, the colour pattern and the size, it is evident that the angular roughsharks encountered were three different individuals. The total length of the sharks was estimated by comparison with the size of the underwater housing of the camera. The sharks initally kept a distance from the divers, apparently disturbed by the light, but then let the divers approach them at very close range and to take close-up pictures of the subjects. Therefore, photographic documentation of the shark was taken on all three encounters.

Eco-tourism, including the activities of shark diving are crucial to draw public attention to the importance of protecting sharks (De Maddalena & Galli, 2017). Currently the Mediterranean Sea offers very few spots where it is possible to have the chance to dive with some species of sharks. Among those documented spots are



Fig. 3: The estimated 50 cm TL angular roughshark observed on the same site on 26 January 2022, at 11:26, at 84 m depth (photo: A. Pagano).
Sl. 3: Približno 50 cm dolga samica morskega prašiča, *Oxynotus centrina****, opažena na isti lokaliteti 26. januarja 2022 ob 11:26, na globini 84 m (foto: A. Pagano).***

the Messina Strait, Italy, for the bluntnose sixgill shark, *Hexanchus griseus* (Bonnaterre, 1788) (Celona *et al.*, 2005), the offshore waters of Beirut, Lebanon, for the smalltooth sand tiger, *Odontaspis ferox* (Risso, 1810) (Barrull & Mate, 2002; De Maddalena *et al.*, 2015), Boncuk Bay, Turkey, Lampione, Italy, Hadera and Ashkelon, Israel, for the sandbar shark, *Carcharhinus plumbeus* (Nardo, 1827), and Hadera and Ashkelon, Israel, for the dusky shark, *Carcharhinus obscurus* (Le Sueur, 1818) (Barash *et al.*, 2018; Zemah Shamir *et al.*, 2019; Kabasakal, 2020; Cattano *et al.*, 2021). The fact that there are so few spots where it is possible to shark dive in the Mediterranean area, makes the site where the three observations of angular roughsark are described in this article even more important. The fact that the species is so uncommon in the entire Mediterranean makes the observation site unique and its preservation critical.

Since female angular roughsharks attain sexual maturity between 66 and 75 cm TL (De Maddalena *et al.*, 2015), we can assume that the female sharks observed off Santa Tecla were sexually mature or subadults, and speculate that perhaps their presence in the area may be related to mating or parturition. Unfortunately, the observation area, despite being also a site for the reproduction of catsharks, *Scyliorhinus* sp., (as clearly shown by egg cases observed by the first author), is not protected in any way. Fishing with gillnets, longlines and pots is still common practice and unregulated. The species is endangered according to the assessment of the IUCN red list (IUCN, 2022) and it's apparently extinct from some locations including the Adriatic Sea and the Gulf of Lion. We strongly recommend the angular roughshark be listed as a protected species, and the site be properly preserved and closely monitored to ensure viable habitat remains.

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PODVODNA OPAZOVANJA REDKEGA MORSKEGA PRAŠIČA, *OXYNOTUS CENTRINA* (CHONDRICHTHYES: SQUALIDAE) V VODAH SANTE TECLE (SICILIJA, ITALIJA)

Alessandro PAGANO
Via Duca degli Abruzzi 40, 95127 Catania, Italy
e-mail: alessandro.pagano@tim.it

Alessandro DE MADDALENA
Shark Museum, 26 Forest Hill Road, Simon's Town, 7975 Cape Town, South Africa
e-mail: alessandrodemaddalena@gmail.com

POVZETEK

Avtorja poročata o treh srečanjih z nenavadnim in izmuzljivim morskim prašičem, Oxynotus centrina*, v bližini Sante Tecle (Catania, Italija), v zahodnem Jonskem morju. Morskega prašiča so opazovali 11. junija 2019, 26. februarja 2020 in 26. januarja 2022, med 74 in 84 m globine. Bile so tri različne samice, vse tudi fotografirane.*

Ključne besede: morski prašič, *Oxynotus centrina*, Sicilija, Jonsko morje, Sredozemsko morje

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MORPHOMETRIC MEASUREMENTS OF THE YOUNG OF THREE CARCHARHINID SPECIES FROM NORTHEASTERN LEVANT (MEDITERRANEAN SEA)

Deniz ERGÜDEN
Marine Sciences Department, Marine Sciences and Technology Faculty, İskenderun Technical University, İskenderun, Hatay, Turkey

Deniz AYAS
Faculty of Fisheries, Mersin, Turkey

Hakan KABASAKAL
Ichthyological Research Society, Ümraniye, İstanbul, Turkey
e-mail: kabasakal.hakan@gmail.com

ABSTRACT

This study presents the morphometric measurements of young individuals of Carcharhinus altimus *(Springer, 1950),* C. obscurus *(Lesueur, 1818), and* C. plumbeus *(Nardo, 1827). These data provide valuable information on the morphometry of the populations of the three species in the northeastern Levant.*

Key words: *Carcharhinus*, morphometry, Levantine Sea, Turkey

MISURE MORFOMETRICHE DEI GIOVANI DI TRE SPECIE DI CARCARINIDI DEL LEVANTE NORD-ORIENTALE (MAR MEDITERRANEO)

SINTESI

Lo studio presenta le misure morfometriche di giovani individui di Carcharhinus altimus *(Springer, 1950),* C. obscurus *(Lesueur, 1818)* e C. plumbeus *(Nardo, 1827). Questi dati forniscono informazioni preziose sulla morfometria delle popolazioni delle tre specie nel Levante nord-orientale.*

Parole chiave: *Carcharhinus,* morfometria, Mar Levantino, Turchia

INTRODUCTION

Since the genus *Carcharhinus* includes some of the largest species of sharks in the Mediterranean waters, a remarkable research effort has been spent by many authors to provide new data for a better understanding of the species of this genus in the entire region (e.g., Capapé, 1984; Hemida *et al*., 2002; Lipej *et al*., 2008; Başusta, 2016; Filiz, 2018; Capapé *et al*., 2018; Azab *et al*., 2019). Due to their vital role in describing fish species (Moyle & Cech, Jr., 1988), morphometric measurements have been reported in most of these studies, and therefore, a remarkable archive of Mediterranean *Carcharhinus* spp. morphometrics is available.

In the present study, the authors report the morphometrics of three species belonging to the genus *Carcharhinus* Blainville, 1816; the bignose shark, *Carcharhinus altimus* (Springer, 1950); the dusky shark, *C. obscurus* (Lesueur, 1818); and the sandbar shark, *C. plumbeus* (Nardo, 1827), which were incidentally captured in the coastal waters of northeastern Levant. The authors also aim to contribute to the available data-set of morphometric measurements



Fig. 1: Map depicting the capture localities of the examined** Carcharhinus altimus **(●),** C. obscurus **(▲) and** C. plumbeus **(■) specimens. Square in the small map indicates the locality in the eastern Levant covered by the present study.
Sl. 1: Zemljevid obravnavanega območja z označenimi lokalitetami, kjer so bili ujeti primerki vrst** Carcharhinus altimus **(●),** C. obscurus **(▲) in** C. plumbeus **(■). Kvadratek na manjšem zemljevidu označuje območje vzhodnega Levanta, obravnavanega v pričujoči raziskavi.

with records of these three Mediterranean carcharhinid species, which may be useful for future research of the same objective.

MATERIAL AND METHODS

Young individuals of *Carcharhinus altimus* (Springer, 1950) (n=6; TL range 54.5–113 cm, mean 73.1±22.3 cm), *C. obscurus* (Lesueur, 1818) (n=1; TL 64.5 cm), and *C. plumbeus* (Nardo, 1827) (n=1; TL 91 cm), were incidentally captured by coastal artisanal long-liners, trammel-netters and gill-netters along the coastline stretching between Dana Island and the mouth of the Göksu River (Fig. 1). *C. plumbeus* is a species protected by the current fisheries law of Turkey and any living sandbar sharks accidentally captured should be immediately released back into the sea. Although not included in the list of protected marine species, based on the researchers' decision, all alive individuals of *C. altimus* and *C. obscurus* in this study were also released due to their conservation status (Data Deficient; Serena *et al*., 2020). Only dead individuals were retained on board and landed. Before performing any observations and incisions on the sharks, the ethic committee approval was acquired for each shark, which was stored in the freezer.

Species identification follows Grace (2001) and Serena (2005), and taxonomic nomenclature follows Serena *et al*. (2020). Measurements were recorded on thawed individuals. Total length (TL) is the distance between the tip of the snout and the tip of the upper caudal lobe, where the upper lobe is in stretched position (Ebert & Stehmann, 2013). Twenty-seven morphometric measurements were taken using a measurement tape and recorded to the nearest 0.1 mm, following the procedure outlined in Ebert and Stehmann (2013). Previously published morphometric measurements of the same species were extracted from the relevant references (Devaraj & Gulati, 2004; Lipej *et al*., 2008; Capapé *et al*., 2018; Azab *et al*., 2019; Lee *et al*., 2019; Ayas *et al*., 2020; Ergüden *et al*., 2020; Turan *et al*., 2020; Froese & Pauly, 2022). All of the measurements were presented as percentages of TL, and for species with multiple individuals, percentages of TL values were computed based on the mean (±SD) of each measurement. The captured individuals were recorded in the Museum of Marine Life, Mersin University with catalogue numbers (MEUFC-22-11-135 - MEUFC-22-11-142). Excel worksheets of the three species are available from the corresponding author for inspection on request.

RESULTS AND DISCUSSION

The main morphological characters allowing us to distinguish the three species of *Carcharhinus* were as follows (Ebert & Stehmann, 2013):

***Carcharhinus altimus* (Springer, 1950)**

Anterior nasal flaps usually high and triangular. Distance from nostrils to mouth less than 2.4 times the mouth width. Upper anterolateral teeth very high; upper anterolateral teeth usually in 15 rows. First dorsal fin lower, with height much less than half predorsal space. Interdorsal ridge high.

***Carcharhinus obscurus* (Lesueur, 1818)**

First dorsal fin origin over or anterior to pectoral fin free rear tips. Pectoral fins large and falcate. Serrations of upper anterolateral teeth small and not very coarse. Inner margin of second dorsal fin shorter and generally less than twice fin height (up to 2.1 times). Interdorsal ridge low.

***Carcharhinus plumbeus* (Nardo, 1827)**

Anterior nasal flaps usually low and inconspicuous. Distance from nostrils to mouth more than 2.4 times the mouth width. Upper anterolateral teeth moderately high; upper anterolateral teeth usually in 14 rows. First dorsal fin very high, with height about half predorsal space. Interdorsal ridge low.

In a recent review of the distribution of chondrichthyans in the Mediterranean Sea, Serena *et al*. (2020) described *C. altimus* as a vagrant species for the Mediterranean Sea, and *C. obscurus* and *C. plumbeus* as resident carcharhinids in the region. The occurrence of these three species in Turkish waters has been mostly reported from Mediterranean coasts, while the distribution of *C. plumbeus* in the region also extends to southern Aegean waters (Kabasakal, 2021).

Since all of the individuals examined had prominent interdorsal ridges (Fig. 2), the *C. brachyurus*, *C. brevipinna*, *C. limbatus,* and *C. melanopterus* species were easily excluded as possibilities. Unlike *C. falciformis*, in which the free rear tip of the 2nd dorsal fin is very long (≥2 to 3 times in 2nd D fin height), the length of the mentioned body part in the examined individuals was shorter (Tables 1–3); as a result, *C. falciformis*, although also exhibiting an interdorsal ridge, was also excluded as a possibility. Six out of the eight examined sharks coincided with the descriptions of *C. altimus,* and the remaining two individuals were identified as *C. obscurus* and *C. plumbeus*, respectively (Grace, 2001; Serena, 2005).

Despite the slight differences, our measurements generally agree with those given by Compagno (1984) for *Carcharhinus* spp. occurring worldwide, and Ebert & Stehmann (2013) for species occurring in the North Atlantic. The percentage of eye length in TL (EYL-TL) in *C. obscurus* (1.8%) fell within the range given by Compagno (1984) and Ebert & Stehmann (2013), which is reported as 1–2.1%. The EYL-TL ratio of *C. altimus* for the mean and maximum



Fig. 2: Some of the specimens of* Carcharhinus *spp. examined in the present study: (a) ventral view of the head and whole lateral view of* C. altimus*; (b) dorsal view of the head and whole lateral view of* C. obscurus*; and (c) ventral view of the head and whole lateral view of* C. plumbeus*. Scale bar = 10 cm.

Sl. 2: Nekaj preiskanih primerkov iz rodu* Carcharhinus *iz te raziskave: a) pogled na glavo vrste* C. altimus *s trebušne strani in pogled z boka; (b) pogled na glavo vrste* C. obscurus *s hrbtne strani in pogled z boka; in (c) pogled na glavo vrste* C. plumbeus *s trebušne strani in pogled z boka. Merilo = 10 cm.

values of the examined specimens (1.5% and 1.7%, respectively), were in agreement with those reported by Compagno (1984) and Ebert & Stehmann (2013), which is 1.4–2.3%; however, the percentage of eye length in TL in the smallest examined specimen (1.2%) was lower than the reported range. In the examined specimen of *C. plumbeus*, the percentage of eye length in TL (1.2%) was also lower than the reported range (1.7–2.9%; Compagno, 1984; Ebert & Stehmann, 2013).

Compagno (1984) and Ebert & Stehmann (2013) reported the percentages of 2nd dorsal fin height in TL (D2H-TL) and pectoral anterior margin length in TL (PAL-TL) in *Carcharninus altimus* as 2.8–3.4% and 20–22%, respectively. Mean and maximum values of D2H-TL and PAL-TL ratios of the examined specimens of *C. altimus* (2.9% and 3.1% for mean and max. D2H-TL, and 17.7% and 17.8% for mean and max. PAL-TL, respectively), coincided with the reported percentages. On the other hand, the same percentages of the smallest examined specimen (2.6% for D2H-TL and 16.5% for PAL-TL) are lower than the above-published percentage ranges. D2H-TL percentages for examined specimens of *C. obscurus* and *C. plumbeus* (2.3% and 3.3%, respectively), are agreed with those reported by Compagno (1984) and Ebert & Stehmann (2013),

Tab. 1: Morphometric measurements of* Carcharhinus altimus *examined in the present study. In bold the percentages mentioned in Compagno (1984) and Ebert & Stehmann (2013).

Tab. 1: Morfometrične meritve na primerkih vrste* Carcharhinus altimus*, preiskanih v pričujoči raziskavi. V mastnem tisku so deleži, ki jih omenjajo Compagno (1984) in Ebert & Stehmann (2013).

Measurements	Present Study (TL range 54.5-113 cm)					Turan *et al.* (2020)		Ayas *et al.* (2020)		Azab *et al.* (2019)		Froese & Pauly (2022) (74 cm TL)
	Mean	SD	% of mean TL	% of min TL	% of max TL	TL	% of TL	TL	% of TL	TL	% of TL	% of TL
Total length (TL)	73.1	22.3				68		65.2		54.6		
Fork length (FL)	58.4	18.0	79.9	79.8	80.5			53.0	81.3		78.7	82.5
Standard length	53.3	16.5	72.9	72.5	73.5	59.0	86.8	48.5	74.4		70.7	79.6
Head length	18.1	4.8	24.7	26.4	23.9	11.1	16.3	15.8	24.2		17.5	
Mouth length	7.0	2.1	9.6	10.1	9.3			5.6	8.6			
Eye length	1.1	0.2	**1.5**	**1.7**	**1.2**	0.8	**1.2**	0.9	**1.4**			
Eye height	1.1	0.2	1.4	1.7	1.2							
Internarial distance	4.5	1.1	6.1	7.3	5.7							
Pre-branchial length	14.8	4.1	20.3	20.2	19.5	9.0	13.2	13.5	20.7			23.5
Pre-orbital length	6.8	1.9	9.3	8.8	8.8			5.8	8.9			
Pre-D1 fin length	22.8	6.8	31.1	31.2	31.0			21.0	32.2			29.9
Pre-D2 fin length	46.9	14.3	64.1	62.4	63.7							
Pre-pectoral fin length	17.8	4.4	24.4	24.8	22.1			13.5	20.7			24
D1 fin length	11.6	4.1	15.8	15.4	16.8			9.6	14.7			
D1 fin height	7.9	2.9	10.8	9.2	11.1			6.4	9.8			
D1 fin base	8.3	2.8	11.4	11.0	11.9			7.0	10.7			
D2 fin length	5.1	1.2	6.9	7.0	4.9			4.5	6.9			
D2 fin height	2.2	0.9	**2.9**	**2.6**	**3.1**	2.0	**2.9**					
D2 fin base	2.9	1.1	3.9	4.4	4.0			2.1	3.2			
Pectoral fin length	13.0	4.3	**17.7**	**16.5**	**17.8**	10.5	**15.4**	13.5	**20.7**			
Pectoral fin base	5.3	2.4	7.3	6.4	8.8			2.8	4.3			
Pelvic fin length	5.8	2.0	8.0	7.3	8.0							
Pelvic fin base	2.6	0.9	3.6	3.3	3.5			2.8	4.3			
Anal fin length	5.8	2.0	7.9	8.3	8.0							
Anal fin base	3.4	1.2	4.6	4.6	4.9			2.4	3.7			
Caudal upper lobe length	19.4	6.2	26.6	26.6	27.0			16.0	24.5			
Caudal lower lobe length	8.1	2.6	11.1	12.8	11.1			6.2	9.5			

Tab. 2: Morphometric measurements of *Carcharhinus obscurus* ***examined in the present study. In bold the percentages mentioned in Compagno (1984) and Ebert & Stehmann (2013). TL of respective specimens examined by Devaraj & Gulati (2004), Azab et al. (2019) and Lee et al. (2019) are given in parentheses under the authors' names.***
Tab. 2: Morfometrične meritve na primerku vrste *Carcharhinus obscurus****, preiskanem v pričujoči raziskavi. V mastnem tisku so deleži, ki jih omenjajo Compagno (1984) in Ebert & Stehmann (2013). Dolžine telesa primerkov, ki jih navajajo Devaraj & Gulati (2004), Azab et al. (2019) in Lee in sod. (2019) so podane v oklepajih pod avtorjevimi imeni.***

Measurements	**Present Study**		**Devaraj & Gulati (2004) (99.5 cm TL)**	**Azab *et al.* (2019) (58.08 cm TL)**	**Lee *et al.* (2019) (83.9 cm TL)**
	cm	**% of TL**	**% of TL**	**% of TL**	**% of TL**
Total length (TL)	64.5				
Fork length (FL)	51	79.1			78.6
Standard length	47.5	73.6	73.2	73.8	71.2
Head length	16.5	25.6	18.5		18.8
Mouth length	6.5	10.1	7.8		
Eye length	1.15	**1.8**	**1.7**	**1.7**	
Eye height	1.05	1.6			
Internarial distance	3.9	6.0			
Pre-branchial length	13	20.2	18.5	5.4	
Pre-orbital length	6	9.3	8.1		
Pre-D1 fin length	19	29.5	31.0	34.2	
Pre-D2 fin length	41	63.6	62.1	63.9	
Pre-pectoral fin length	16	24.8	21.2	22.6	
D1 fin length	10	15.5			
D1 fin height	6.5	10.1	8.1	11.2	
D1 fin base	8	12.4	8.6	82.4	
D2 fin length	4.5	7.0		3.0	
D2 fin height	1.5	**2.3**	**2.0**		
D2 fin base	2.5	3.9	2.8	2.2	
Pectoral fin length	10	**15.5**	**11.5**	**16.1**	
Pectoral fin base	5	7.8	5.2	5.9	
Pelvic fin length	5	7.8		4.0	
Pelvic fin base	2	3.1	4.2		
Anal fin length	4.9	7.6		4.7	
Anal fin base	2.5	3.9	3.6	2.8	
Caudal upper lobe length	17	26.4	25.5	27.1	
Caudal lower lobe length	7	10.9	10.6	11.8	

Tab. 3: Morphometric measurements of* Carcharhinus plumbeus *examined in the present study. In bold the percentages mentioned in Compagno (1984) and Ebert & Stehmann (2013).
Tab. 3: Morfometrične meritve na primerku vrste* Carcharhinus plumbeus*, opravljene v pričujoči raziskavi. V mastnem tisku so deleži, ki jih omenjajo Compagno (1984) in Ebert & Stehmann (2013).

Measurements	**Present Study**		**Lipej *et al.* (2008)**			**Capapé *et al.* (2018)**		**Ergüden *et al.* (2020)**	
	cm	**% of TL**	**Mean**	**SD**	**% of mean TL**	**cm**	**% of TL**	**cm**	**% of TL**
Total length (TL)	91		74.3	6.2		89		68	
Fork length (FL)	72.5	79.7	59.8	5.4	80.5				
Standard length	65	71.4	54.7	5.1	73.6				
Head length	22.5	24.7	19.1	1.9	25.7	17	19.1	16.7	24.6
Mouth length	8	8.8	7.2	0.5	9.6	8	9.0		
Eye length	1.1	**1.2**	1.0	0.2	**1.4**	1.1	**1.2**	0.9	**1.3**
Eye height	0.9	1.0	1.1	0.1	1.4	1.2	1.3		
Internarial distance	5.3	5.8	4.5	0.3	6.0	5	5.6		
Pre-branchial length	19	20.9	14.8	1.6	19.9	16.5	18.5		
Pre-orbital length	8.5	9.3	6.5	1.0	8.7				
Pre-D1 fin length	28.5	31.3	21.5	1.7	28.9				
Pre-D2 fin length	59	64.8	46.7	3.8	62.8				
Pre-pectoral fin length	23	25.3	17.2	2.0	23.1				
D1 fin length	14.5	15.9	10.4	0.3	14.0	12	13.5	12	17.6
D1 fin height	10.5	11.5	7.2	1.0	9.6				
D1 fin base	10	11.0	9.0	0.3	12.1	10	11.2		
D2 fin length	7	7.7	3.1	0.3	4.2	4	4.5	5.4	7.9
D2 fin height	3	**3.3**	2.3	0.5	**3.1**				
D2 fin base	3.5	3.8	2.9		3.9	4	4.5		
Pectoral fin length	15.5	**17**	12.5	0.7	**16.9**	14	**15.7**	9.2	**13.5**
Pectoral fin base	7	7.7	4.9	0.6	6.6	5.5	6.2		
Pelvic fin length	7	7.7	6.0	0.6	8.0	4	4.5	5.8	8.5
Pelvic fin base	3.5	3.8	3.1	0.3	4.1	4	4.5		
Anal fin length	7	7.7	5.6	0.3	7.6	5	5.6	5.3	7.8
Anal fin base	4	4.4	3.1	0.3	4.2	3.5	3.9		
Caudal upper lobe length	25	27.5	10.6	1.1	14.3	22	24.7		
Caudal lower lobe length	9	9.9	5.2	0.5	7.0	8	9.0	6	8.8

of which as 1.5-2.3% for *C. obscurus* and 2.1-3.5% for *C. plumbeus*. Similarly, PAL-TL percentages of *C. obscurus* and *C. plumbeus* (1.5% and 17%, respectively) were within the ranges reported for *C. obscurus* (17–22%) and *C. plumbeus* (17–22%) by Compagno (1984) and Ebert & Stehmann (2013).

The slight variations between our measurements and those given by Compagno (1984) and Ebert & Stehmann (2013) suggest incongruity with the published descriptive ratios; however, similar variations have been observed in young individuals of the present *Carcharhinus* spp. before. When comparing our results to those reported for young individuals of *C. altimus*, *C. obscurus* and *C. plumbeus* from several regions of the Mediterranean Sea and elsewhere in the world (Devaraj & Gulati, 2004; Lipej *et al.*, 2008; Capapé *et al.*, 2018; Azab *et al.*, 2019; Lee *et al.*, 2019; Ayas *et al.*, 2020; Ergüden *et al.*, 2020; Turan *et al.*, 2020; Froese & Pauly, 2022; Tables 1–3) it is clear that the results concerning the three examined carcharhinid species from our study coincide better with the percentages reported by the above authors for young specimens (bold numbers in the relevant tables) than they do with those reported by Compagno (1984) and Ebert & Stehmann (2013) for adult individuals.

The percentage of EYL-TL of the examined specimens of *Carcharhinus altimus* was in agreement with those reported by Ayas *et al.* (2020) and Turan *et al.* (2020) (Table 1). The percentage range of D2H-TL of the examined specimens of *C. altimus* was also within the range reported by Turan *et al.* (2020); however, the percentage of PAL-TL of the examined specimens exceeded the percentage range reported by Ayas *et al.* (2020), and was higher than the ratio reported by Turan *et al.* (2020) (Table 1). Specimens of *C. altimus* reported by Ayas e*t al.* (2020) and Turan *et al.* (2020) were also incidentally captured in the vicinity of the present sampling localities.

The EYL-TL percentages in the present specimen of *Carcharhinus obscurus* and in the Indian Ocean specimen reported by Devaraj & Gulati (2004) are in agreement with the percentage range reported for dusky sharks from Korean waters (Lee *et al.*, 2019) (Table 2), and the percentage of D2H-TL for the present specimen fits within the range reported by Lee *et al.* (2019), as well (Table 2). The PAL-TL percentages reported for the present specimen (15.5%) and for the Indian Ocean specimen (16.1%; Devaraj & Gulati, 2004) both exceed the range recorded in Korean dusky sharks (11.5–13.9%; Lee *et al.*, 2019).

For *Carcharhinus plumbeus*, the EYL-TL, D2H-TL, and PAL-TL percentages recorded in the present specimen differ from those recorded in specimens reported by Lipej *et al.* (2008), Capapé *et al.* (2018) and Ergüden *et al.* (2020), standing at 1.2 vs. 1.4%, 3.1 vs. 3.3% and 13.5 vs. 17%, respectively (Table 3).

CONCLUSIONS

Due to similar body shapes, colours and overlapping distributions, the Carcharhinidae genera can generally be difficult to identify, particularly *Carcharhinus* spp. (Grace, 2001). Since the existing literature addressing worldwide distribution (e.g., Compagno, 1984) or covering wide marine regions (*e.g*,. Serena, 2005; Ebert & Stehmann, 2013) may not be applicable to carcharhinids occurring in Turkish waters, a set of multiple descriptions including a broad range of ratios and characters may be needed for their identification, as was the case in the present study. Identification of *Carcharhinus* spp. is facilitated by division into two groups based on the presence or absence of an interdorsal ridge. The origin of the first dorsal fin in relation to the pectoral fin and also the snout shape are useful for further subdivision of each group and, ultimately, species identification. This conventional order of division of characteristics follows the accepted identification keys (e.g., Compagno, 1984; Grace, 2001; Serena, 2005; Ebert & Stehmann, 2013), so what could be the underlying reasons for the differences in morphometric percentages?

Geographically distant (allopatric) populations of the same fish species tend to exhibit morphometric characters at the opposite margins of the value ranges (Cailliet *et al.*, 1986). The morphometric differences seen in the present study can thus be considered admissible based on the above-mentioned situation. Although the morphometric data reported for *Carcharhinus altimus*, *C. obscurus* and *C. plumbeus* in the present study provide valuable information on the morphometry of their populations in the northeastern Levant, it is clear that morphometric analysis of more specimens of each *Carcharhinus* species are required to obtain statistically significant results.

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MORFOMETRIČNE MERITVE MLADIČEV TREH VRST MORSKIH PSOV IZ DRUŽINE CARCHARHINIDAE IZ SEVERNOVZHODNEGA LEVANTA (SREDOZEMSKO MORJE)

Deniz ERGÜDEN
Marine Sciences Department, Marine Sciences and Technology Faculty, İskenderun Technical University, İskenderun, Hatay, Turkey

Deniz AYAS
Faculty of Fisheries, Mersin, Turkey

Hakan KABASAKAL
Ichthyological Research Society, Ümraniye, İstanbul, Turkey
e-mail: kabasakal.hakan@gmail.com

POVZETEK

Avtorji poročajo o morfometričnih meritvah na mladih primerkih vrst Carcharhinus altimus *(Springer, 1950),* C. obscurus *(Lesueur, 1818) in* C. plumbeus *(Nardo, 1827). Te meritve nudijo pomembne podatke o morfometriji populacij treh vrst v severovzhodnem Levantu.*

Ključne besede: *Carcharhinus*, morfometrija, Levantsko morje, Turčija

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PROJECTIONS ON THE FUTURE OF DEEP-SEA SHARKS IN THE SEA OF MARMARA, WHERE DEEP ZONES ARE THREATENED BY DEOXYGENATION: A REVIEW

Hakan KABASAKAL
Ichthyological Research Society, Tantavi mahallesi, Menteşoğlu caddesi, İdil apartmanı, No: 30, D: 4, Ümraniye, TR-34764 İstanbul, Turkey
e-mail: kabasakal.hakan@gmail.com

ABSTRACT

Among the 14 species of sharks occurring in the Sea of Marmara, bathidemersal species, which spend most of the day in bathyal depths over continental slopes or in trenches, constitute approximately 43% (6 species) of the sharks in the region. These species are: Hexanchus griseus, Echinorhinus brucus, Oxynotus centrina, Centrophorus *cf.* uyato, Dalatias licha *and* Galeus melastomus. *For the last 30 years, amounts of dissolved oxygen in the deep layers of the Sea of Marmara have been below the levels required for the survival of marine life. It seems that deep-sea sharks are increasingly occupying the niches of other species living on the continental shelf of the Sea of Marmara. The impact of this situation on fisheries and the possible responses of commercial fishers to this ecological uncertainty cannot be predicted for now. Therefore, both scientific researchers and policy makers need to identify specific measures for an effective protection of sharks in the Sea of Marmara, giving priority to the most threatened species.*

Key words: Deep-sea, sharks, Marmara, hypoxia, habitat, conservation, bycatch

PROIEZIONI SUL FUTURO DEGLI SQUALI DI ACQUE PROFONDE NEL MARE DI MARMARA, DOVE LE ZONE PROFONDE SONO MINACCIATE DALLA DEOSSIGENAZIONE: UNA RASSEGNA

SINTESI

Tra le 14 specie di squali presenti nel Mar di Marmara, le specie batidemersali che trascorrono la maggior parte del giorno in acque profonde su pendii continentali o in trincee, costituiscono circa il 43% (6 specie) degli squali della regione. Queste specie sono: Hexanchus griseus, Echinorhinus brucus, Oxynotus centrina, Centrophorus *cf.* uyato, Dalatias licha *e* Galeus melastomus. *Negli ultimi 30 anni, le quantità di ossigeno disciolto negli strati profondi del Mar di Marmara sono state inferiori ai livelli necessari alla sopravvivenza della vita marina. Sembra che gli squali di acque profonde stiano occupando sempre più le nicchie di altre specie che vivono sulla piattaforma continentale del Mar di Marmara. L'impatto di questa situazione sulla pesca e le possibili risposte dei pescatori commerciali a questa incertezza ecologica non possono essere al momento previste. Pertanto, sia i ricercatori scientifici che i responsabili politici hanno bisogno di identificare le misure specifiche per una protezione efficace degli squali nel Mar di Marmara, dando priorità alle specie più minacciate.*

Parole chiave: squali di acque profonde, Marmara, ipossia, habitat, conservazione, bycatch

INTRODUCTION

With approximately 1200 species, the cartilaginous fish, including sharks and their relatives (stingrays, skates, manta rays, rat fishes etc.) (Dulvy *et al*., 2021) are an evolutionary success story that has been unfolding in the world's oceans for approximately 400 million years (Fowler *et al*., 2005). Sharks, inhabiting very diverse habitats in the oceans worldwide, distributed from the shallows of fresh and coastal waters to the open ocean, from the continental shelf to the deep continental slope and deep waters up to 4000 m (Fowler *et al*., 2005). Deep-sea sharks account for more than half (approximately 56%, 278 species) of modern sharks and approximately 45 percent of all deepwater cartilaginous fish today (536 species) (Kyne & Simpfendorfer, 2007; Dulvy *et al*., 2021). According to Kyne and Simpfendorfer (2007) and Ebert (2013), all shark species whose distribution is restricted to waters deeper than 200 m or which spend a significant part of their life cycle at depths greater than 200 m are defined as "deep-sea sharks."

Currently, there are 38 shark species occurring in Turkish seas (Kabasakal, 2021; Turan *et al*., 2021) and 14 shark species in the Sea of Marmara (Kabasakal, 2022). Of the 14 species occurring in the Sea of Marmara, bathidemersal species, which spend most of the day in bathyal depths over the continental slope or in deep trenches, constitute approximately 43 percent (6 species) (Kabasakal, 2022).

Globally, overfishing and bycatch appear to be two major threats to the survival of sharks and cartilaginous fish in general (Fowler *et al*., 2005). According to Dulvy *et al*. (2021) overfishing alone is considered a threat that affects approximately 67 percent of all species. While sharks (and cartilaginous fish in general) are supposed to have been little affected by human activity in the pre-industrial era, the drastic changes in nature and the environment caused by the increase in human population following industrialization has had a dramatic impact on the lives of these species (Fowler *et al*., 2005). Today, not only overfishing, but also degradation and loss of habitats, climate change and pollution are seriously effecting shark survival (Dulvy *et al*., 2021). From this point of view, "deoxygenation" (Vedor *et al*., 2021; Mantıkçı *et al*., 2022), one of the severest consequences of human-induced pollution and climate change in the seas, is another growing problem triggering catastrophic changes in marine life and generating dramatic mortalities (Vaquer-Sunyer & Duarte, 2008).

Marmara is a small inland sea, where hypoxic (<80 μM O_2) conditions occur in deep demersal regions, and even in the Çınarcık trench (or deep depression), which is the deepest part of the Sea of Marmara, anoxic conditions impend (Mantıkçı *et al*., 2022). Among the extant members of the bathyal fauna, which deoxygenation is expected to affect dramatically, are deep-sea sharks. This review article puts forth a series of literature-based projections on the future that may await deep-sea sharks in the Sea of Marmara if the current situation of deoxygenation does not improve. The possible effects of hypoxia on the bycatch and conservation of deep-sea sharks in the region are also discussed.

MATERIAL AND METHODS

This review article presents the current status of dissolved oxygen in the Sea of Marmara and hypoxia values in deep sea trenches based on data provided by Mantıkçı *et al*. (2022) and CSB (2021–2024). The general characteristics of the deep-sea shark species with confirmed occurrence in the Sea of Marmara (Kabasakal, 2021, 2022), their depth distributions (Serena, 2005), and Red List conservation statuses (global assessment, IUCN, 2022; Mediterranean assessment – Otero *et al*., 2019; *Centrophorus cf. uyato*, Mediterranean assessment – Serena *et al*., 2020) are given in Table 1.

RESULTS AND DISCUSSION

General remarks on the Sea of Marmara

The Sea of Marmara, which constitutes the Turkish Straits system together with the Istanbul (Bosphorus) and Çanakkale (Dardanelles) Straits, is a characteristic and small inland sea located at the center of the mentioned system (Kocatas et al, 1993; Ozturk & Ozturk, 1996) (Fig. 1). Based on Kocatas *et al*. (1993) and Öztürk & Öztürk (1996), the general characteristics of the Sea of Marmara can be summarized as follows: although it is a very small inland sea with an area of 11,500 km^2 and a volume of 3.378 km^3, it occupies an important place in Turkey's fishing economy. Three neighboring deep sea trenches (or deep depressions), a narrow continental shelf in the north, and a relatively wider continental shelf in the south are the main geomorphological formations that stand out in its bottom structure (Fig. 1). The depression zone located in the middle region and reaching 1335 m in depth is the sea's deepest area. The current dynamics exhibit a dual current system pattern, as the Sea of Marmara is connected by the Bosphorus and the Dardanelles to the Black Sea, and to the Aegean and Mediterranean Seas, respectively. Considering the temperature and salinity stratification, three different water layers fill the Marmara basin: surface, bottom, and transitional layers. The renewal time of the volume of water in the Sea of Marmara with the oxygen rich flow from the Mediterranean and the Aegean Sea, is estimated at 6 to 7 years (Kocataş *et al*., 1993).

General remarks on the deep-sea sharks of the Sea of Marmara

Although the number of studies on the deep-sea sharks of the Sea of Marmara started to increase in the 1990s, these species had been briefly mentioned already in two earlier studies that hold an important place in the history of Turkish ichthyology (Ninni, 1923; Deveciyan, 1926). Ninni (1923) and Deveciyan (1926) stated that *Hexanchus griseus* and *Echinorhinus brucus* lived in the mentioned area, without giving detailed information. According to Deveciyan (1926), the deep-sea shark species *E. brucus* was at that time quite abundant in the region. In an ichthyology inventory published in the early 1940s, Erazi (1942) included to the species list *Oxynotus centrina* as one of the sharks living in the Bosphorus and in the Sea of Marmara. Between1940s and the early 1990s, there was a deep silence in which no significant study was carried out on the deep-sea sharks of the area. The capture of 5 individuals of *Centrophorus granulosus* in autumn 1992 during a scientific bottom-trawl expedition at a depth of 400 m (Benli *et al.*, 1993)

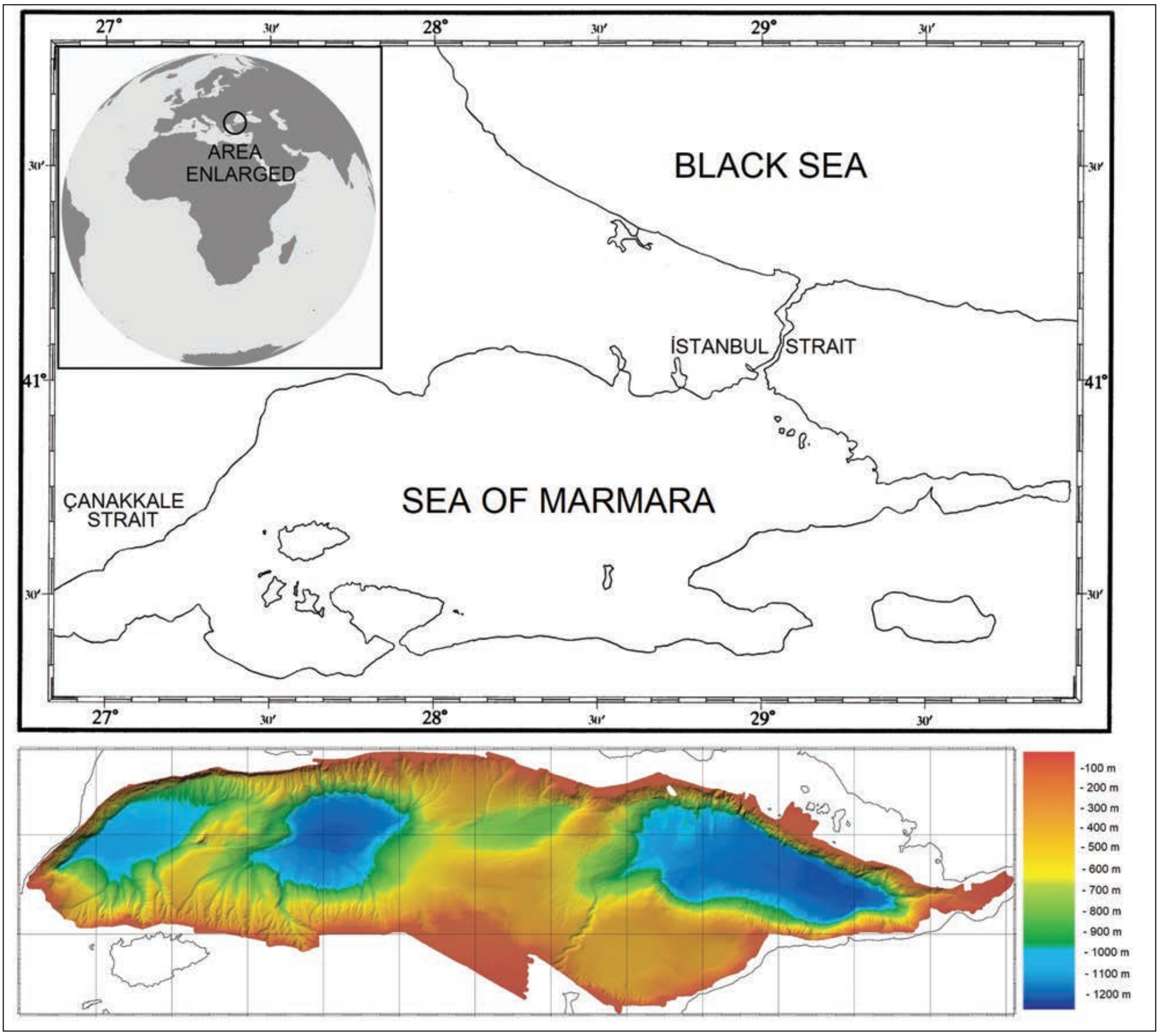
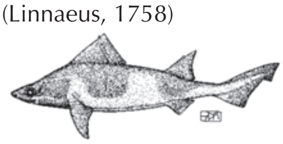


Fig. 1: Geographical position and bathymetry of the Sea of Marmara. The dark blue areas in the map below indicate deep trenches or deep depressions. Bathymetry map derived from Claude et al. (2001).
Sl. 1: Geografski položaj in batimetrija Marmarskega morja. Temno modra območja na spodnjem zemljevidu označujejo globinske jarke ali globoke depresije. Batimetrična karta je povzeta po Claude in sod. (2001).

Tab. 1: Depth ranges, general remarks and Red List statuses of deep-sea sharks recorded in the Sea of Marmara. NT: Near Threatened; LC: Least Concern; EN: Endangered; CR: Critically Endangered; VU: Vulnerable. *Mediterranean and worldwide (Serena, 2005; Ebert & Stehmann, 2013; Sion et al., 2004); depths of sighting or fishing in the Sea of Marmara in bold based on the following references: Kabasakal (2013, 2015, 2017), Kabasakal & Bilecenoğlu (2014), Kabasakal et al. (2005), Meriç (1995), Oral (2010). ‡Serena (2005). †IUCN Global Red List Status (IUCN, 2022); Conservation Status in the Mediterranean (Otero et al., 2019; Serena et al., 2020). (Drawings by Alessandro De Maddalena).

Tab. 1: Globinski razponi, splošne opombe in statusi na rdečem seznamu globokomorskih morskih psov, zabeleženih v Marmarskem morju. NT: Skoraj ogrožen; LC: Najmanjša skrb; SL: Ogrožen; CR: kritično ogrožen; VU: Ranljiv. *Sredozemsko morje in po vsem svetu (Sion in sod., 2004; Serena, 2005; Ebert & Stehmann, 2013); globine opazovanja ali ribolova v Marmarskem morju (mastni tisk) na podlagi naslednjih referenc: Kabasakal (2013, 2015, 2017), Kabasakal & Bilecenoğlu (2014), Kabasakal in sod. (2005), Meriç (1995), Oral (2010). ‡Serena (2005). † Status vrst na podlagi svetovnega rdečega seznama IUCN (IUCN, 2022); status v Sredozemlju (Otero in sod., 2019; Serena in sod., 2020). (Risbe Alessandra De Maddalene).

Species	Depth range (m)*	Genaral remarks‡	Red List Status†
Hexanchus griseus (Bonnaterre, 1788) 	100-2500 / **10-1000**	Rarely caught as bycatch by bottom trawls and longlines in epibathyal and bathyal grounds. Occasionally a target species. Usually occurs in deep and cool waters, close to the bottom, possibly rising to surface at night. Ovoviviparous, litters of about 20 to 50, possibly up to 100 embryos.	Global: NT Med: LC
Echinorhinus brucus (Bonnaterre, 1788) 	200-900 / **45-1214**	Bycatch in trawl fisheries. Occasionally on shallow shelf areas, mostly deep waters, also found inshore in cold-temperate areas. Probably ovoviviparous.	Global: EN Med: EN
Centrophorus cf. *uyato* (Rafinesque, 1810) 	50-1400, usually 500-1000 / **150-400**	Occasionally caught as bycatch by deep bottom trawls and longlines. Benthic on outer shelf and upper slope. Ovoviviparous usually with only one young, born at 40 cm TL. Females mature at 75 to 89 cm, males at 81 to 94 cm TL.	Global: EN Med: CR
Oxynotus centrina (Linnaeus, 1758) 	60-800 / **30-200**	Bycatch in deep-sea trawling. Benthic on continental shelf and upper slope. Ovoviviparous with probably 7 or 8 young. Maturing at about 50 to 70 cm.	Global: EN Med: CR
Dalatias licha (Bonnaterre, 1788) 	90-1000, usually 300-600 / **270**	Bycatch in bottom trawl fishery. Benthic to mesopelagic, mainly on slopes. Ovoviviparous, 3 to 16 juveniles born at 30 cm. Maturing at 77 to 121 cm for males and 117 to 159 cm for females.	Global: VU Med: VU
Galeus melastomus Rafinesque, 1810 	200-1200, usually 300-400 / **200-1000**	Bycatch of deepsea trawl fisheries. Benthic, from upper continental slope to bathyal grounds. Feeds on bottom-living invertebrates and fishes, also scavenger. Oviparous, spawning all year round with a peak in spring and summer. Males mature at 34 to 42 cm, females 38 to 45 cm.	Global: LC Med: LC

revived the research of deep-sea sharks occurring in the region. Although *C. granulosus* is not accepted as a valid species today (Serena *et al.*, 2020), these 5 individuals were considered as the first record of *C. granulosus* in the Sea of Marmara in those years. A few years later, Meriç (1995) recorded *Centrophorus* cf. *uyato* and *Dalatias licha* for the first time in the waters of the northern slope. Meriç (1995) also recorded *H. griseus*, *C. granulosus,* and *Galeus melastomus* and contributed new information on their regional presence. Since the valid species of the genus *Centrophorus* in the Mediterranean is currently *C.* cf. *uyato* (Serena *et al.*, 2020), the individuals previously identified as *C. granulosus* by Benli *et al*. (1993) and Meriç (1995) should be reidentified.

Studies carried out in the following years suggest that *Hexanchus griseus* is the most abundant deep-sea shark found in the continental slope and bathyal grounds of the Sea of Marmara (Kabasakal, 2013, 2017). Although *Oxynotus centrina*, previously recorded by Erazi (1942), mainly occurs in the waters of the continental slope (Kabasakal, 2015), it is known that it makes temporary visits to shallow coastal waters during night time for feeding purposes (Kabasakal, 2009). The angular roughshark *O. centrina*, which can reach depths of approximately 800 m (Ebert & Stehmann, 2013), is rarely seen in northern and southern continental shelf waters, between depths of 30 and 50 m, (Kabasakal, 2009; Bayhan *et al.*, 2006). The species *Echinorhinus brucus*, which was considered extinct in the area due to its absence in fishing records of the second half of the 20th century, was video-imaged at a depth of 1214 m in northern Marmara in October 2002 (Kabasakal *et al.*, 2005), and this sighting was followed by several incidental captures of the species in this region (Kabasakal, 2017; Kabasakal & Bilecenoğlu, 2014). When the usual depth distribution of the species is taken into account (200–1214 m; Serena, 2005; Kabasakal *et al.*, 2005), the capture of an individual of *E. brucus* in the southwestern Sea of Marmara on 24 January 2017, draws attention due to its shallow depth (45 m; Kabasakal, 2017). According to Uysal *et al*. (1996), *Galeus melastomus* is a rare species, distributed in the Sea of Marmara in waters deeper than 200 m. Oral (2010) made a preliminary study on the stomach contents of a *G. melastomus* and confirmed that the species mostly occurs at depths exceeding 1000 m in the Marmara bathyal.

The habitats, depth ranges, availability and IUCN protection statuses of deep-sea sharks in the Sea of Marmara are given in Table 1.

Deoxygenation in the Sea of Marmara and assumed

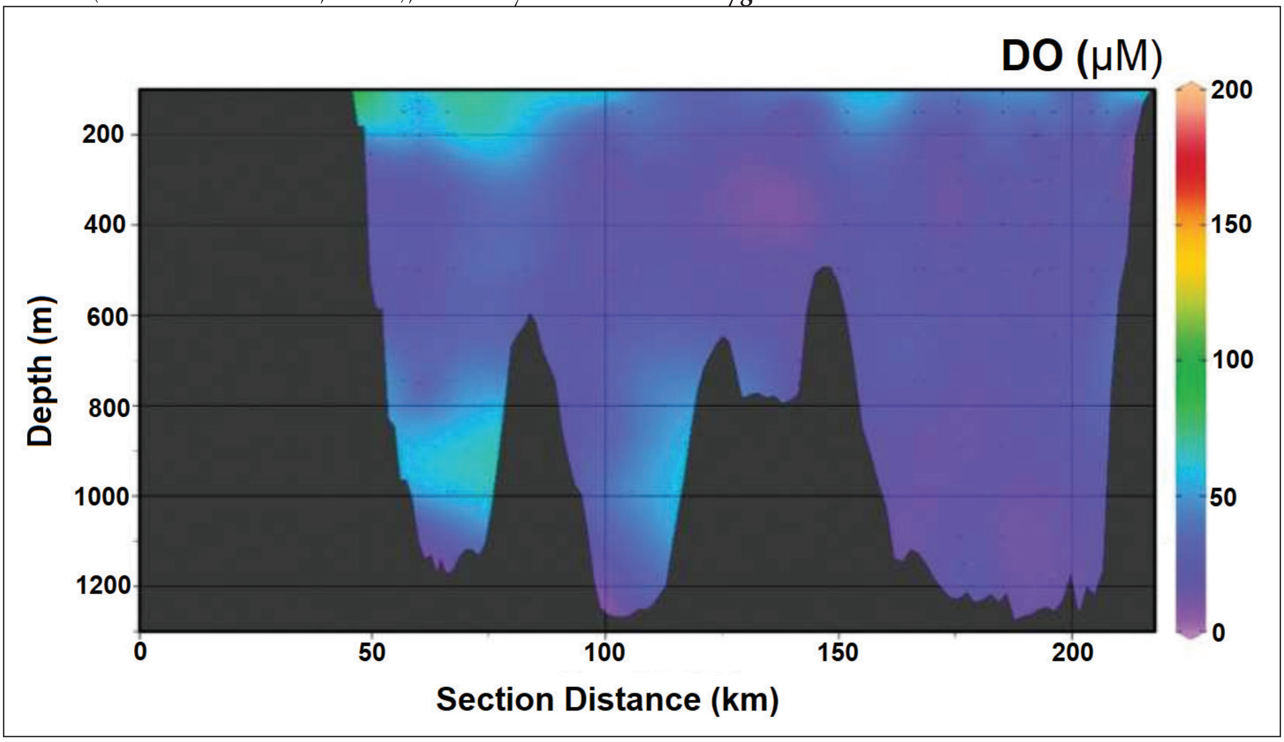


Fig. 2: Dissolved oxygen (DO) in the water column of the Sea of Marmara (2010–2017 period). Graph derived from CSB (2021–2024; Fig. 2.16, page 46).
Sl. 2: Raztopljeni kisik (DO) v vodnem stolpcu Marmarskega morja (obdobje 2010–2017). Graf, povzet po CSB (2021–2024; sl. 2.16, stran 46).

"vertical habitat compression" of deep-sea sharks

In their review of fishery resources and current environmental conditions in the Sea of Marmara in the early 1990s, Kocataş *et al*. (1993) stated that the average amount of dissolved oxygen in the region was 7.6 mg/l, with the oxygen-rich layer extending to a depth of 45 m, and even 80 m in some places. Although the amount of dissolved oxygen decreases with increasing depth, Kocataş *et al*. (1993) emphasized that at the deepest points of the Sea of Marmara dissolved oxygen was still at the level of 5 mg/l. Given that dissolved oxygen should be <2 mg/l for fisheries to collapse or benthic fauna elements to exhibit abnormal behavior or for signs of hypoxia to occur (Diaz & Rosenberg, 2008; Vaquer-Sunyer & Duarte, 2008), until the 1990s the Sea of Marmara appeared to have enough dissolved oxygen to support life down to the deepest point of the entire water column. In the last 40 years, it has been observed that the oxygen values in the deepest regions of this sea have fallen below 80 µmol, which is considered the limit of hypoxia, due to increased human activity (Mantıkçı *et al*., 2022; Salihoğlu *et al*., 2022) (Fig. 2). According to Mantıkçı *et al*. (2022), anoxic conditions are about to occur in the Çınarcık Trench (1335 m), which is the deepest point of the Sea of Marmara.

Sharks are active predators and many of them are ram ventilators with very high absolute oxygen requirements and although hypoxia can significantly affect their physiology, behavior and ecology, even forcing them to migrate (Sims, 2019), little research has been done on the impact of hypoxic waters on their ecology, behavior and distribution. Still, it is known from current studies that sharks show remarkable tolerance to poor hypoxia conditions, changing their behavior, and that some bathymersal species can even persist in deep hypoxic regions for long periods of time during the day (Carlson & Parsons, 2001; Jorgensen *et al*., 2009; Coffey & Holland, 2015; Comfort & Weng, 2015; Vedor *et al*., 2021).

Although active predators are expected to avoid prolonged exposure to hypoxic waters, the bluntnose sixgill shark (*Hexanchus griseus*) is frequently seen in hypoxic waters (<60 µmol; 535 m ± 15 m) around Hawaii (Comfort & Weng, 2015) (Fig. 3). In another study examining the distribution of *H. griseus* in hypoxic waters, sharks with dissolved oxygen pop-up satellite archival tags (DO-PAT) were observed to for a long time (> 6 hours) at depths where dissolved

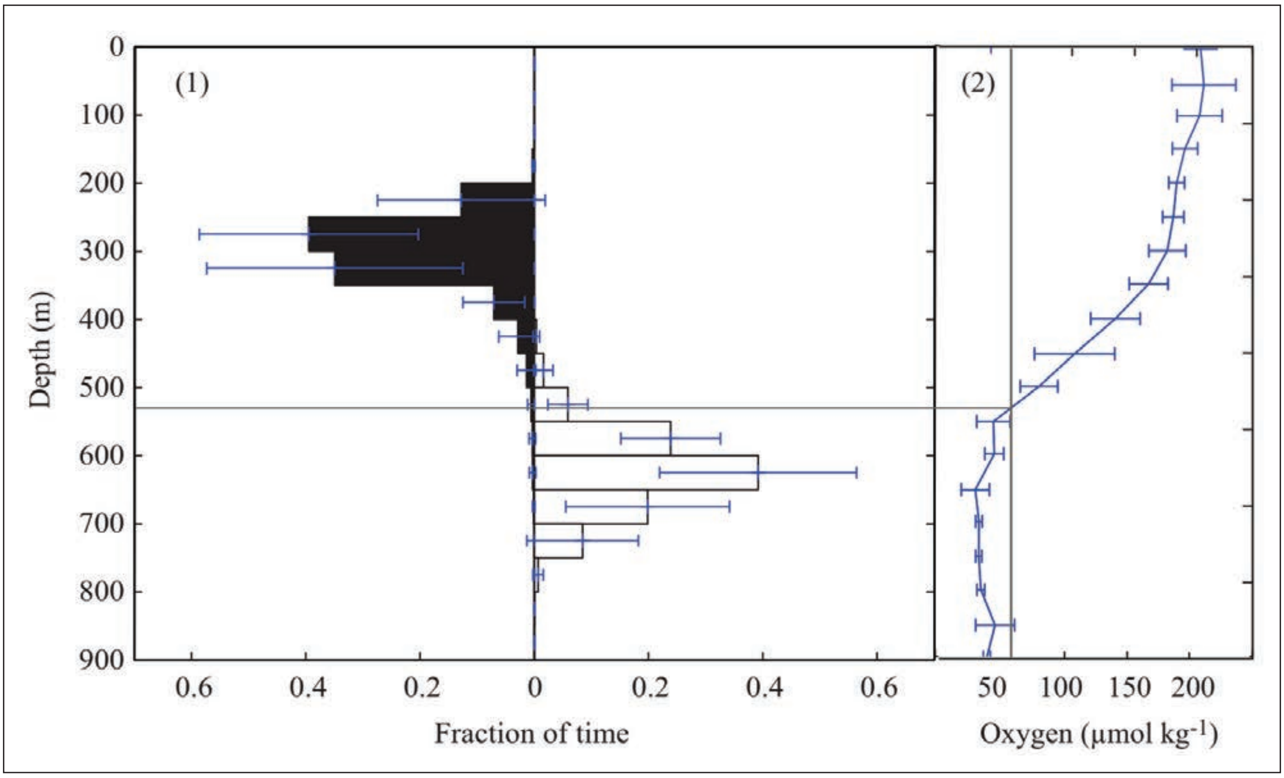


Fig. 3: Time spent by *Hexanchus griseus* ***in oxygen minimum zone in Hawaii waters, obtained through DO-PAT deployment. Graph derived from Comfort & Weng (2015; Fig. 2, page 120).***
Sl. 3: Čas, ki ga je morski pes šesteroškrgar *(Hexanchus griseus)* ***preživel v minimalnem območju kisika v havajskih vodah, pridobljen z uporabo DO-PAT. Graf povzet po Comfort & Weng (2015; sl. 2, stran 120).***

oxygen saturation was as low as 9.4% (depth 687 m) (Coffey & Holland, 2015).

Observations of Comfort and Weng (2015) and Coffey and Holland (2015) indicate that *H. griseus* can withstand hypoxic conditions and does not leave its usual deep-water habitat immediately. It can be assumed, therefore, that as long as complete anoxia does not develop in the deep trenches of the Sea of Marmara, the *H. griseus* population inhabiting these regions will not leave its habitat. However, should the amount of dissolved oxygen drop to levels below the oxygen requirements of the species (in the worst case scenario, zero), it can be expected that the bluntnose sixgill sharks will be forced to leave the deep regions and permanently inhabit coastal waters as a result of vertical habitat compression. The depths of capture of individuals of *H. griseus* in commercial fishery in the Black Sea appear to support this assumption.

The species *Hexanchus griseus* was first recorded in the Black Sea in Prebosphoric waters, on 5 February 2001, followed by individuals caught in Amasra (central Black Sea) in November 2004 and Şile (western Black Sea) in October 2006 (Kabasakal, 2013). All 3 individuals were caught in continental shelf waters at depths shallower than 100 m. A recent capture of *H. griseus* in coastal waters off Trabzon (eastern Black Sea) was reported in 23 December 2021 (Hakan Kabasakal pers. obs.). Oxygen-saturated waters represent only 12% of the total water volume of the Black Sea, and deeper waters (deeper than 125–224 m) are contaminated with hydrogen sulfide (Prodanov *et al.*, 1997). The Black Sea bathyal waters preferred by *H. griseus* under normal conditions (Serena, 2005) have turned into anoxic dead zones (Diaz, 2016). The presence of *H. griseus* in the shallow waters of a sea the depth range of which can extend to 2500 m under normal conditions (Ebert & Stehmann, 2013) can be a result of "vertical habitat compression" (Coffey & Holland, 2015) due to deoxygenation. In recent years, almost all of the incidental captures of *H. griseus* have been recorded in the continental shelf (<200 m depth) and the species has almost never been encountered in deeper parts of the continental slope and the bathyal zone (Kabasakal, 2017). This is likely the result of "vertical habitat compression" caused by deoxygenation, the effect of which is increasing gradually in the depths of the Sea of Marmara as well (Mantıkçı *et al.*, 2022).

The vertical distribution of *Oxynotus centrina* in the Sea of Marmara also seems to have been affected by deoxygenation in deep waters. This species, which is normally distributed up to depths of 800 m (Sion *et al.*, 2004), can make temporary excursions to coastal waters during night-time (Kabasakal, 2009). However, catch records of the species in this sea in the last 10 years reveal that bycatch of *O. centrina* has also been concentrated in the continental shelf (<100 m depth) (Kabasakal 2015, 2017; Bayhan *et al.*, 2006).

Although one of the deepest sightings of the bathydemersal bramble shark, *Echinorhinus brucus*, was recorded in the Sea of Marmara (1214 m; Kabasakal *et al.*, 2005), the distribution of this taxon in the mentioned region has also begun to concentrate in the upper zones of the continental slope and continental shelf in recent years (Kabasakal, 2017; Kabasakal & Bilecenoğlu, 2014). On the other hand, *Dalatias licha* and *Centrophorus* species have not been observed again after being recorded in the waters of the northern continental slope in the 1990s (Meriç, 1995; Benli *et al.*, 1993), and their current existence in the Sea of Marmara is questionable (Kabasakal, 2022). *Galeus melastomus* is the only species that has been sampled in the deep depression regions of Marmara in the last 10 years (Oral, 2010).

In a study examining shark response to oxygen depletion in the environment, Carlson and Parsons (2001) found that *Sphyrna tiburo* (Sphyrnidae) and *Carcharhinus acronotus* (Carcharhinidae), which are obligatory ram ventilators, respond to oxygen depletion by increasing their swimming speed, while the buccal ventilating demersal shark *Mustelus norrisi* (Triakidae) reduces its activity. Although the physiological responses of deep-sea sharks in the Sea of Marmara to deoxygenation are currently unknown, "vertical habitat compression" (Diaz & Rosenberg, 2008; Coffey & Holland, 2015; Vedor *et al.*, 2021) or "forced migration" (Vaquer-Sunyer & Duarte, 2008) are predictable. Parallel to the steadily increasing deoxygenation in the Sea of Marmara in recent years, the depths of incidental capture of deep-sea sharks have reduced, confirming this prediction, *Galeus melastomus* being the only exception.

Implications of deoxygenation for the bycatch, survival and conservation of deep-sea sharks in the Sea of Marmara

Overfishing or bycatch (Dulvy *et al.*, 2021), which represents the main threat to the survival of sharks worldwide, is also the main cause of mortality among the sharks of the Sea of Marmara (Meriç, 1995; Bayhan *et al.*, 2006; Bök *et al.*, 2011; İşmen *et al.*, 2013; Kabasakal, 2022). However, deteriorating environmental conditions, climate change, degradation and loss of habitat are now also putting their existence at risk (Dulvy *et al.*, 2021). It is important to understand how deoxygenation (Vaquer-Sunyer & Duarte, 2008), which forces marine life to migrate and leads to drastic reductions in biodiversity,

will affect the distribution and abundance of sharks in a given region, and to anticipate how this might interact with bycatch in commercial fisheries (Sims, 2019).

"Vertical habitat compression" triggered by deoxygenation and the resulting concentration of sharks in areas where dissolved oxygen is available are expected to increase deaths from bycatch (Sims, 2019; Vedor *et al.*, 2021). In a study examining individuals of *Hexanchus griseus* caught in Turkish seas between 1967 and 2013, Kabasakal (2013, 2017) stated that in the Sea of Marmara, where most of the incidental captures of the bluntnose sixgill sharks occurred (60%; n=90), captures began to concentrate in continental shelf waters (<200 m depth) following a deterioration in environmental conditions (Fig. 4). Based on that available evidence it can be supposed that the increase of captures of *H. griseus* in the continental shelf of the Sea of Marmara in recent years is likely due to "vertical habitat compression" resulting from deoxygenation in the bathyal zone. In order to understand how the depth distribution of *H. griseus* in the Sea of Marmara is affected by deoxygenation, a DO-PAT study as in Coffey and Holland (2015) and Comfort and Weng (2015) should be conducted here as well. *Oxynotus centrina* and *Echinorhinus brucus*, which also occur in continental slope or bathyal regions, have also been caught more frequently as bycatch in the shallow areas of the continental shelf in recent years (Kabasakal, 2015, 2017; Kabasakal & Bilecenoğlu, 2014) (Fig. 4). It appears that bathyal hypoxia is forcing these two shark species, which are rare in the Sea of Marmara, to migrate to surface waters.

As to the protection status of deep-sea sharks in the Sea of Marmara, 2 species (*Hexanchus griseus* and *Galeus melastomus*) are considered as Least Concern, 1 species (*Echinorhinus brucus*) as Endangered, 1 species (*Dalatias licha*) as Vulnerable and 2 species (*Centrophorus* cf. *uyato* and *Oxynotus centrina*) as Critically Endangered (Otero *et al.*, 2019; Serena *et al.*, 2020) (Table 1). As two of these species (*C.* cf. *uyato* and *D. licha*) have not been recorded in scientific expeditions or in commercial

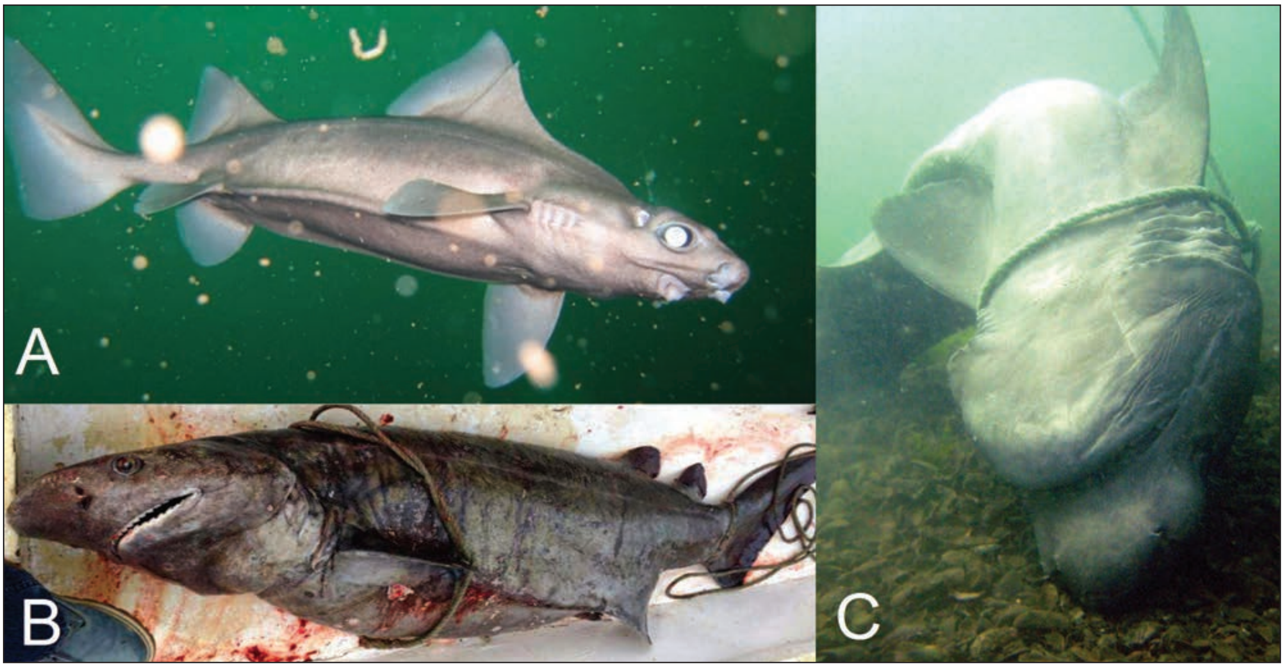


Fig. 4: Deep-sea sharks sighted or bycaught in continental shelf waters of the Sea of Marmara. (A) *Oxynotus centrina***, sighted at a depth of 35 m in northeastern Sea of Marmara (Photo: P. İnce); (B)** *Echinorhinus brucus***, entangled in commercial gill-net at a depth of 45 m in southwestern Sea of Marmara (Photo: Ichthyological Research Society Archives); and (C)** *Hexanchus griseus***, captured by a commercial beam-trawler in Prebosphoric shelf waters (Photo: H. Kabasakal).**

Sl. 4: Globokomorski morski psi, opaženi ali ulovljeni v vodah kontinentalne police Marmarskega morja. (A) *Oxynotus centrina***, opažen na globini 35 m v severovzhodnem Marmarskem morju (Foto: P. İnce); (B)** *Echinorhinus brucus***, ujet v komercialno zabodno mrežo na globini 45 m v jugozahodnem Marmarskem morju (Foto: Arhiv Ichthyological Research Society); in (C)** *Hexanchus griseus***, ki so ga ujeli ribiči z vlečnimi mrežami v predbosporskih vodah na kontinentalni polici (Foto: H. Kabasakal).**

fishery since the 1990s, they might have been extirpated or are even extinct in the area. There is an urgent need for the conservation of the remaining species, *H. griseus*, *G. melastomus,* and *E. brucus*, to update their conservation status to Critically Endangered in the Sea of Marmara, where bycatch pressure is intense and vertical habitats are likely to be compressed due to hypoxic bathyal waters. Except for *O. centrina*, none of the other species is under protection in Turkey (Kabasakal, 2021). Due to the nature of K-selective life histories (long life, sexually late maturation, low fecundity) (Fowler *et al*., 2005), once populations of sharks' decline, it may take many years for them to recover. Add the effects of vertical habitat compression to those of the existing bycatch, and the survival of deep-sea shark species in the Sea of Marmara, where many are already classified as "rare," is under serious question.

CONCLUSIONS

For the last 30 years, amounts of dissolved oxygen in the deep layers of the Sea of Marmara have been below the levels required for the survival of marine life (Mantıkçı *et al*., 2022). While deep-sea sharks seem to be increasingly occupying the niches of other species living in the waters of the continental shelf in the Sea of Marmara, the impact of that on fisheries and the responses of commercial fishers to this ecological uncertainty are currently impossible to predict. However, from available evidence it is clear that bycatch rates of deep-sea sharks in the Sea of Marmara are increasing as a result of the species migrating to the continental shelf, which negatively affects their survival. It has been estimated for the Sea of Marmara that if the release of anthropogenic and terrestrial pollutants causing deoxygenation into marine environment decreased by 40%, the hypoxia could be reversed in 6 years (Salihoğlu *et al*., 2022). However, as Diaz and Rosenberg (2008) stated, even if oxygen levels normalize, there is a possibility that faunal recolonization may not revert to pre-hypoxia levels. Therefore, both scientific researchers and policy makers need to identify region-specific measures for an effective protection of sharks in the Sea of Marmara, giving priority to the most threatened species. Given that the Marmara bathyal may take 6 years at best to return to normal oxygen conditions, these measures are an urgency that cannot be ignored, as shark populations are expected to concentrate in the waters of the continental shelf, and currently these species are still little affected by bycatch.

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NAPOVEDI O PRIHODNOSTI GLOBOMORSKIH MORSKIH PSOV V MARMARSKEM MORJU, OGROŽENEM ZARADI POMANJKANJA KISIKA: PREGLED

Hakan KABASAKAL

Ichthyological Research Society, Tantavi mahallesi, Menteşoğlu caddesi, İdil apartmanı, No: 30, D: 4, Ümraniye, TR-34764 İstanbul, Turkey

e-mail: kabasakal.hakan@gmail.com

POVZETEK

Med 14 vrstami morskih psov, ki se pojavljajo v Marmarskem morju, je približno 43% (6 vrst) batidemerzalnih morskih psov v regiji, ki večino dneva preživijo v velikih globinah in globokomorskih jarkih. To so: Hexanchus griseus*,* Echinorhinus brucus*,* Oxynotus centrina*,* Centrophorus *cf.* uyato*,* Dalatias licha *in* Galeus melastomus*. V zadnjih 30. letih so bile količine raztopljenega kisika v globokih plasteh Marmarskega morja pod ravnmi, ki so potrebne za preživetje morskega življenja. Zdi se, da globokomorski morski psi vse bolj zasedajo niše drugih vrst, ki živijo na kontinentalni polici Marmarskega morja. Vpliv teh sprememb na ribištvo in možni odzivi komercialnih ribičev na to ekološko negotovost za zdaj ni mogoče predvideti. Zato morajo tako raziskovalci kot politiki opredeliti posebne ukrepe za učinkovito zaščito morskih psov v Marmarskem morju, pri čemer bi morali dati prednost najbolj ogroženim vrstam.*

Ključne besede: globokomorski morski psi, Marmara, hipoksija, habitat, ohranjanje narave, prilov

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DISTRIBUTION EXTENSION OF *LUTJANUS ARGENTIMACULATUS* (LUTJANIDAE) AND *PSENES PELLUCIDUS* (NOMEIDAE) TO THE WATERS OF MALTA, CENTRAL MEDITERRANEAN SEA

Alan DEIDUN
Department of Geosciences, University of Malta, Msida MSD 2080, Malta
e-mail: alan.deidun@um.edu.mt

Bruno ZAVA
Museo Civico di Storia Naturale, via degli Studi 9, 97013 Comiso (RG), Italy
Wilderness studi ambientali, via Cruillas 27, 90146 Palermo, Italy
e-mail: wildernessbz@hotmail.com

Maria CORSINI-FOKA
Hellenic Centre for Marine Research, Institute of Oceanography, Hydrobiological Station of Rhodes. Cos Street, 85100 Rhodes, Greece
e-mail: mcorsini@hcmr.gr

ABSTRACT

The recent first findings of the Lessepsian migrant Lutjanus argentimaculatus (Forsskål, 1775) *and of the Atlantic range-expanding* Psenes pellucidus Lütken, 1880 *in the waters of Malta, central Mediterranean, are described. The current distribution in the basin of these two fish species is briefly discussed.*

Key words: Non-Indigenous species, Lessepsian migration, range-expanding species, Mediterranean Sea, citizen science

ESPANSIONE DELLA DISTRIBUZIONE DI *LUTJANUS ARGENTIMACULATUS* (LUTJANIDAE) E DI *PSENES PELLUCIDUS* (NOMEIDAE) VERSO LE ACQUE DI MALTA, MEDITERRANEO CENTRALE

SINTESI

Nell'articolo vengono segnalati i primi recenti ritrovamenti nelle acque di Malta, Mediterraneo centrale, del migrante lessepsiano Lutjanus argentioomaculatus (Forsskål, 1775) *e di* Psenes pellucidus Lütken, 1880, *una specie di origine atlantica, il cui areale è in espansione. L'attuale distribuzione di queste due specie nel bacino è brevemente discussa.*

Parole chiave: Specie non-indigene, migrazione Lessepsiana, specie di origine atlantica in espansione, Mediterraneo, citizen science

INTRODUCTION

In the Mediterranean Sea, most of the Non-Indigenous Species (NIS) of fishes are of Indo-Pacific origin, introduced via the Suez Canal (Lessepsian migrants); other species, of diverse origins, have entered into the basin via human-mediated activities (ship-transport, mariculture, aquarium trade) (Golani *et al.*, 2021). Furthermore, a number of fishes of Atlantic origin, named range-expanding, newcomers, neonative species, entered naturally into the basin through the Strait of Gibraltar (Evans *et al.*, 2020).

Four species of Lutjanidae have been detected in the Mediterranean, *Lutjanus argentimaculatus* (Forsskål, 1775), *Lutjanus fulviflamma* (Forsskål, 1775), and *Lutjanus sebae* (Cuvier, 1816), all native to the Red Sea and the Indo-West Pacific (Vella *et al.*, 2015; Deidun & Piraino, 2017; Golani & Fricke, 2018; Akyol, 2019) and *Lutjanus jocu* (Bloch & Schneider, 1801) originating from the western and eastern Atlantic (Vacchi *et al.*, 2010).

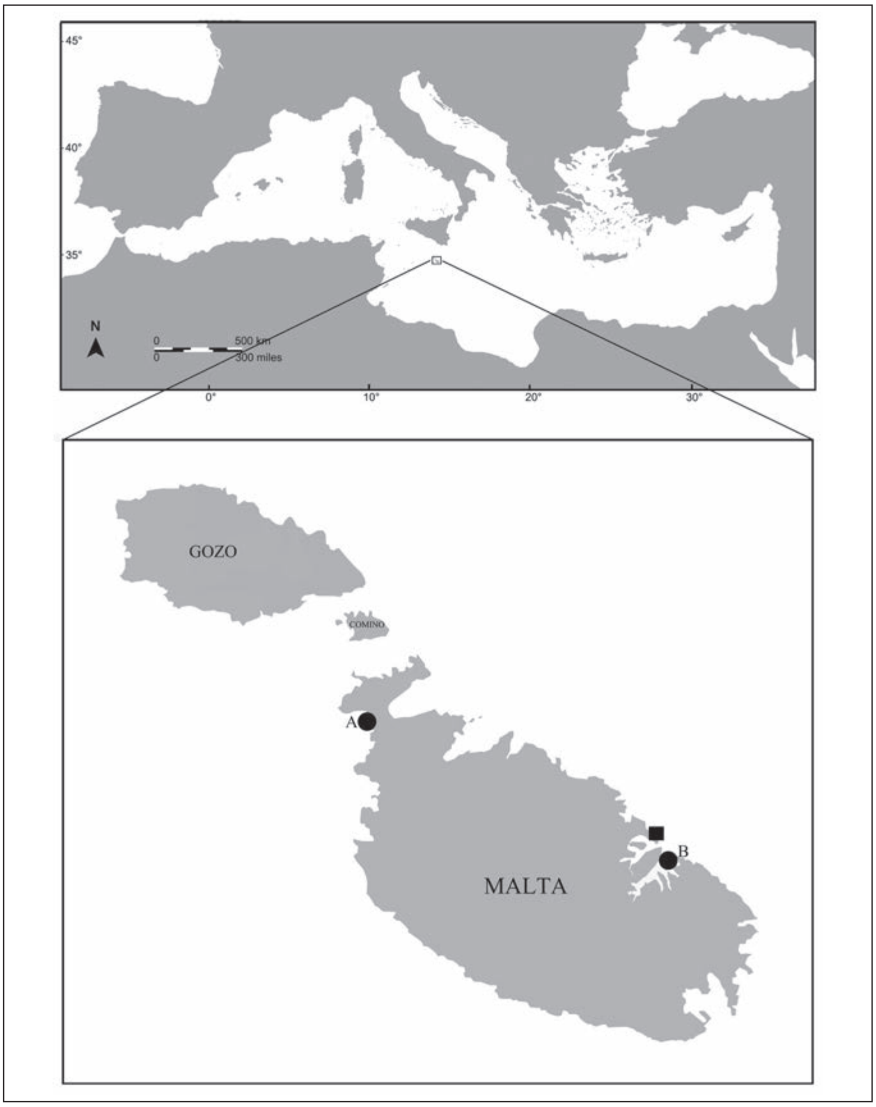


Fig. 1: Maps of the Mediterranean Sea and the Malta Archipelago, showing the finding locations of *Lutjanus argentimaculatus* ***at Sliema (square), and*** *Psenes pellucidus* ***at Anchor Bay (A) and Grand Harbour, Valletta (B), in Malta Island (circle).***
Sl. 1: Zemljevid Sredozemskega morja in malteškega arhipelaga z označenimi lokalitetami na Malti, kjer sta bili najdeni vrsti *Lutjanus argentimaculatus* ***na lokaliteti Sliema (kvadratek) in*** *Psenes pellucidus* ***na lokalitetah Anchor Bay (A) in Grand Harbour, Valletta (B) (krogca).***



Fig. 2: *Lutjanus argentimaculatus* ***spearfished in Malta (photo: R. Mizzi).***
Sl. 2: *Lutjanus argentimaculatus* ***ulovljen s podvodno puško na Malti (foto: R. Mizzi).***

According to Kovačić *et al*. (2021), the family Nomeidae is represented in the Mediterranean by *Cubiceps capensis* (Smith, 1845), *Cubiceps gracilis* (Lowe, 1843) and *Psenes pellucidus* Lütken, 1880, all circumglobal species in warm and temperate seas. Among the above named nomeids, the latter one, *P. pellucidus*, is generally considered as a recent, naturally range-expanding species from the Atlantic (Evans *et al*., 2020; Golani *et al*., 2021).

The first findings of the Indo-Pacific NIS *L. argentimaculatus* and of the Atlantic range-expanding *P. pellucidus* in the waters of the island of Malta are described and the distribution of their records in the Mediterranean is briefly discussed.

MATERIAL AND METHODS

Photographic material and capture data of fishes were obtained from the "Spot the Alien" platform, a citizen science campaign implemented since 2017 by the Oceanography Malta Research Group within the Department of Geosciences at the University of Malta.

On 12 January 2021 a specimen of the Mangrove red snapper *Lutjanus argentimaculatus*, 43.0 cm of total length, weighing 1.63 kg, was speared at Sliema (Malta) (35.911958°N, 14.509129°E) at 12 m of depth (Fig. 1). The sample was not preserved.

On 13 February 2022 a small specimen of the Bluefin driftfish *Psenes pellucidus*, approximately 50 mm in total length (TL) (specimen A), was collected at Anchor Bay, Malta (35.959923° N, 14.340031° E) (Fig. 1) from the shore with a hand-net, next to a specimen of *Pelagia noctiluca*. The sample was photographed alive and released, while another similar individual (about 100 mm in length) was only observed. On 12 March 2022, a second small specimen (specimen B), about 40 mm in total length, was collected at the Grand Harbour, Valletta, Malta (35.893415° N, 14.525980° E) (Fig. 1) from the shore through rod-fishing, using common shrimps as bait, at an estimated depth of 4-5 m. The specimen was photographed, but not collected. It is to be stressed that a large-scale bloom of jellyfish, primarily consisting of salps, *P. noctiluca* and of ctenophores, has been observed in the waters of Malta since December 2021 (AD, personal observation).

RESULTS

Lutjanus argentimaculatus (Forsskål, 1775)

The specimen was identified as *L. argentimaculatus* following Allen (1985) and Anderson & Allen (2001), on the basis of the available photo (Fig. 2): body moderately deep, pointed snout and terminal mouth, a notch in the lower margin of the oper-

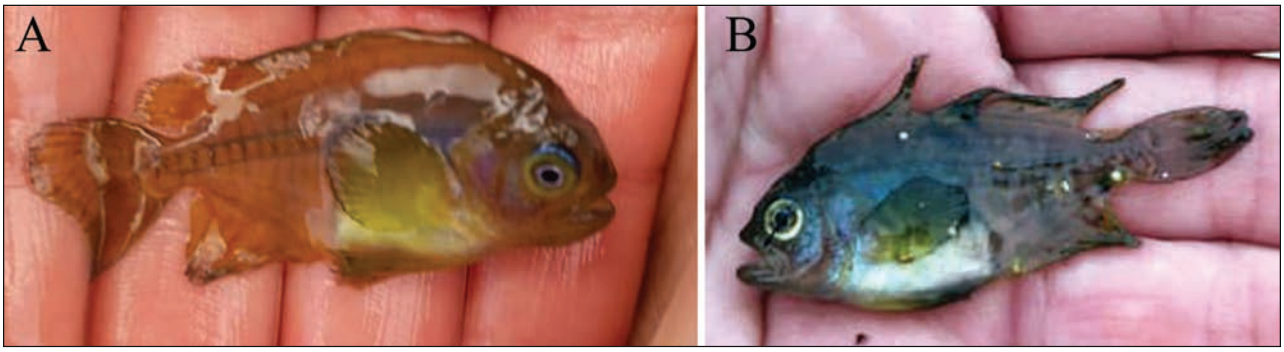


Fig. 3: Juveniles of *Psenes pellucidus* ***from Malta. A: live specimen collected in February 2022 (photo: A. Misfud), B: specimen collected in March 2022 (photo: M. Etienne).***
Sl. 3: Mladostni primerki vrste *Psenes pellucidus* ***iz Malte. A: živi primerek, ulovljen februarja 2022 (foto: A. Misfud), B: ujeti primerek iz marca 2022 (foto: M. Etienne).***

culum, scale rows on back parallel to lateral line, apart the last rows rising obliquely posteriorly under the end of soft dorsal, caudal fin nearly truncate. Colour: body reddish, darker on back and sides, lighter on belly; silver shadings are visible; dorsal and anal fins dusky brownish, caudal fin dusky brownish with the outer margin paler, pectoral and pelvic fins reddish.

Psenes pellucidus Lütken, 1880

The fishes were identified as juveniles of *P. pellucidus* on the basis of the photos available (Fig. 3A, B), following Lütken (1880), Haedrich (1967), Ahlstrom *et al*. (1976), Costa (1999), Lamkin (2005), Fahay (2007), Hata & Motomura (2017), Cabebe & Motomura (2019) and Bray (2020). The body of the *P. pellucidus* juveniles (Fig. 3A, B) appears moderately high and compressed with a flabby consistence; the head shows a concavity over the eye; two dorsal fins, the origin of the first over the posterior end of the gill opening, the origin of the second over the end of the upper margin of the pectoral fin; the posterior end of the dorsal fin base is located just above the posterior end of the anal fin base; the pectoral fin has round margin, the upper origin of its base is under the posterior end of the gill opening; the caudal fin is lightly emarginated, with rounded lobes; the pelvic fin origin is under the pectoral fin base. Anal fin appears high. The mouth is small, with the upper jaw ending about below the middle of the lower margin of the eye. As observed by the persons who collected the specimens, the fishes were almost transparent, acquiring, during photography, a reddish translucent coloration in specimen A, alive (Fig. 3A) and a bluish-violet translucent colouration in specimen B, dead (Fig. 3B). The ventral part, between pectoral and pelvic fins, appears whitish, not translucent; a bluish curved shadow from the upper gill opening to the origin of anal fin is visible in the live specimen (Fig. 3A); the pectoral fin is prevalently golden; the outer margin of dorsal, anal, pelvic and caudal fins appears darker than the remaining fin; the iris appears silvery around the crystalline, with a posterior darker shadow, then golden with a lunate dark blue band at the superior margin (Fig. 3A). From Fig. 3A it was possible to obtain a limited number of approximate ratios: head length 34.9, pectoral fin length 28.5, body depth 43.4, caudal peduncle height 7.4, eye diameter 10.8, maxillary length 13.1, all expressed as % of standard length.

DISCUSSION

The description of the *Lutjanus argentimaculatus* specimen from Malta was in agreement with that provided by Allen (1985) and Anderson & Allen (2001) for the species.

The mangrove red snapper *L. argentimaculatus* is a large fish of a common size to 80 cm (maximum 120 cm), with a wide Indo-West Pacific distribution extending from the Red Sea and eastern Africa to Australia and Samoa (Allen, 1985; Sonin *et al*., 2019; Golani *et al*., 2021). It was first recorded in the Mediterranean by Mouneimné (1979) from Lebanon, considered to have been introduced via the Suez Canal (Lessepsian migrant) (Golani & Fricke, 2018). A second record was reported again from Lebanon, in 2014 (Crocetta & Bariche, 2016), after a time interval lasting about four decades and widely discussed in Sonin *et al*. (2019). From 2018 to date, other findings in the eastern Mediterranean followed: east Aegean, Turkey (Akyol, 2019), Israel (Sonin *et al*., 2019), southwest Aegean, Greece (Tiralongo *et al*., 2019) and Cyprus (Langeneck *et al*., 2022).

The Maltese record of the Lessepsian migrant *L. argentimaculatus* described in the present paper is the first for the central Mediterranean Sea and could constitute a first indication that the species, already established in the eastern basin (Sonin *et al.*, 2019), is expanding its population westward. The quick succession of new Mediterranean records of the species in recent years suggests that this expansion is happening rapidly.

Concerning *Psenes pellucidus*, the description of the young specimens from Malta agreed with that of similarly-sized specimens described for example in Costa (1999), Hata & Motomura (2017) and Cabebe & Motomura (2019). The approximate ratios obtained for our specimen were comparable to the corresponding ratios for *P. pellucidus* given by Hata & Motomura (2017), except for that of body depth. The transparence and the lack of bands and spots of our young *P. pellucidus* allowed to differentiate them from the early stages of other *Psenes* species, unrecorded in the Mediterranean, such as *P. maculatus* Lütken, 1880, *P. cyanophrys* Valenciennes, 1833 and *P. arafurensis* Günther, 1889 (Fahay, 2007; Myoung *et al.*, 2001; Cabebe & Motomura, 2019). Furthermore, our samples were distinguishable from the juvenile stages of the Mediterranean Centrolophidae *Centrolophus niger* (Gmelin, 1789), *Schedophilus ovalis* (Cuvier, 1833) and *Schedophilus medusophagus* (Cocco, 1839), because these latter have a single dorsal fin, their young stages are pigmented with dark spots or bands, and *Schedophilus* species have denticulate preoperculum (Tortonese, 1959; Ahlstrom *et al.*, 1976; Aboussouan, 1983; Costa, 1999; Fahay, 2007; Akyol, 2008; Milana *et al.*, 2011; Dulčić *et al.*, 2012; Rafrafi-Nouira *et al.*, 2015). The *P. pellucidus* samples from Malta were also distinguishable from juveniles of the other nomeids known in the Mediterranean, *C. gracilis* and *C. capensis*, having these latter a more elongated body (Fahay, 2007).

The Bluefin driftfish *P. pellucidus* reaches a length of 60-80 cm and is widely distributed in the temperate and warm waters of the Atlantic, Indian and western Pacific oceans (Golani *et al.*, 2021). It is an oceanic species with epipelagic or mesopelagic juveniles, often associated with jellyfish and floating objects, while large adults are prevalently demersal on the continental slope (Golani *et al.*, 2021). In the Mediterranean, *P. pellucidus* was first recorded in Algeria (Dieuzeide & Roland, 1955) and, as mentioned above, it is considered a range-expanding species introduced via the Strait of Gibraltar (Evans *et al.* 2020; Golani *et al.*, 2021). Subsequent records were reported in the western and central basin, from Morocco (Maurin, 1962, 1968), Spain (Riera *et al.*, 1995), France (Quignard & Tommasini, 2000), Italy, in the Strait of Messina since 1992 and later (Costa & Fanara, 1994; Berdar *et al.*, 1995; Spalletta *et al.*, 1995; Costa, 1999; Navarra *et al.*, 2007; Orsi-Relini, 2010), and Sardinia (Follesa *et al.*, 2006), as well as from Tunisia (Ghanem *et al.*, 2016). Although it is a fish not frequently caught in the basin, *P. pellucidus* is considered as established in northeastern Sicilian waters (Sperone *et al.*, 2015); in particular, the collection of juveniles of this species is probably correlated to the abundance of ctenophores and cnidarians along the coasts of the Strait of Messina (Navarra *et al.*, 2007) as in the case for juvenile fishes of other medusivorous species in the same area (Battaglia *et al.*, 2014).

The first record of *P. pellucidus* from Malta is currently the easternmost one for the whole Mediterranean and could anticipate that the species is facing a further extension of its distribution toward the eastern part of the basin. It is known that the diet of *P. pellucidus*, at least during its juvenile stages, includes the jellyfish *Pelagia noctiluca* (Navarra *et al.*, 2007). The current winter bloom of *Pelagia noctiluca* observed in Malta could have played a role in the dispersal of juveniles *P. pellucidus* to the waters of the island, as hypothesized in the case of the juvenile specimen found in Tunisian waters (Ghanem *et al.*, 2016).

The findings from this study further reinforce the significance of the Strait of Sicily, east of which the Malta archipelago is located, as an ecological corridor for the east-west and west-east dispersion of exotic species and Atlantic range-expanding species within the Mediterranean basin respectively, i.e., as a biogeographical crossroads between the two parts of the basin (Guidetti *et al.*, 2010; Deidun *et al.*, 2011, 2021a, b; Azzurro *et al.*, 2014).

Constant monitoring of biodiversity in this region is fundamental for the anticipation of new arrivals from east toward the west and vice versa, so as to alert and inform environmental managers and policy-makers of the possible expansion of their populations in the contiguous areas.

Citizen science is giving an important contribution to the enhancement of knowledge on marine biodiversity and for the monitoring of species (native, NIS and neonative species) distributions. Fully in agreement with Karachle *et al.* (2020), it is nevertheless essential to verify species identification through the scientific examination of samples reported by citizens in platforms and social media, given that the submission by the public of photographic material or videos, the quality of which is often poor, is clearly insufficient to enable the correct taxonomic identification of species and could lead to approximate or incorrect conclusions on their occurrence in the basin. There is no doubt that social media and new technologies are powerful instruments for the rapid exchange of information

and photos on biota, but there is a dire need to improve the collaboration between citizen scientists and scientists (Roy *et al.*, 2018). This collaboration, for example, could lead scientists to provide clear guidance to the public on how to correctly position samples pursuant to taking good-quality photos as well as on sound specimen preservation.

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ŠIRJENJE AREALA VRST *LUTJANUS ARGENTIMACULATUS* (LUTJANIDAE) IN *PSENES PELLUCIDUS* (NOMEIDAE) V MALTEŠKE VODE (OSREDNJE SREDOZEMSKO MORJE)

Alan DEIDUN
Department of Geosciences, University of Malta, Msida MSD 2080, Malta
e-mail: alan.deidun@um.edu.mt

Bruno ZAVA
Museo Civico di Storia Naturale, via degli Studi 9, 97013 Comiso (RG), Italy.
Wilderness studi ambientali, via Cruillas 27, 90146 Palermo, Italy
e-mail: wildernessbz@hotmail.com

Maria CORSINI-FOKA
Hellenic Centre for Marine Research, Institute of Oceanography, Hydrobiological Station of Rhodes. Cos Street, 85100 Rhodes, Greece
e-mail: mcorsini@hcmr.gr

POVZETEK

Avtorji poročajo o recentnem prvem zapisu o pojavljanju lesepske selivke Lutjanus argentimaculatus (Forsskål, 1775) in širjenju areala atlantske vrste Psenes pellucidus Lütken, 1880 *v malteške vode (osrednje Sredozemsko morje). Nadalje na kratko razpravljajo o sedanji razširjenosti obeh vrst.*

Ključne vrste: tujerodne vrste, lesepska selitev, vrste, ki širijo areal, Sredozemsko morje, ljubiteljska znanost

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FIRST RECORD OF *ENCHELYCORE ANATINA* (MURAENIDAE) FROM LIBYAN WATERS AND AN ADDITIONAL RECORD FROM SOUTHERN ITALY (WESTERN IONIAN SEA)

Sami M. IBRAHIM & *Abdulrraziq A. ABDULRRAZIQ*
Department of Marine Resources, Tobruk University, Tobruk, Libya

Abdulghani ABDULGHANI
Department of Marine Resources, Omar Al-Moukhtar University, El Bayda, Libya
Marine Biology in Libya Society, El Bayda, Libya

Sara A.A. AL MABRUK
Department of General Nursing Technology, Higher institute of Science and Technology, Cyrene, Libya
Marine Biology in Libya Society, El Bayda, Libya

David SALVATORI
Via Elio Lucci 56, 00052 Cerveteri (Roma), Italy

Bruno ZAVA
Wilderness studi ambientali, via Cruillas 27, 90146 Palermo, Italy
Museo Civico di Storia Naturale di Comiso, via degli Studi 9, Comiso (RG), Italy

Maria CORSINI-FOKA
Institute of Oceanography, Hellenic Centre for Marine Research. Hydrobiological Station of Rhodes, Cos Street, 85100 Rhodes, Greece
e-mail: mcorsini@hcmr.gr

Alan DEIDUN
Department of Geosciences, University of Malta, Msida MSD 2080, Malta

ABSTRACT

In the Bomba Gulf, Tobruk, eastern Libya, a specimen of the fangtooth moray, Enchelycore anatina (*Lowe, 1839*), *was caught in gill nets at approximately 20 m of depth. An additional observation of the species from southern Calabria, Italy, is also reported. The findings of this range-expanding species of Atlantic origin document the first record from Libyan waters and from the southern shores of the Mediterranean Sea as well as the expansion of the species' distribution in western Ionian waters.*

Key words: Non-Indigenous Species (NIS), Atlantic range-expanding species, neonative species, *Enchelycore anatina*, Libya, Italy, Mediterranean Sea

PRIMO RITROVAMENTO DI *ENCHELYCORE ANATINA* (LOWE, 1839) (MURAENIDAE) IN ACQUE LIBICHE E ULTERIORE SEGNALAZIONE IN ITALIA MERIDIONALE (MAR IONIO OCCIDENTALE)

SINTESI

Un esemplare di Enchelycore anatina (*Lowe, 1839*) *è stato pescato con tramaglio nel Golfo di Bomba, Tobruk, in Libia orientale, a circa 20 m di profondità. La specie è stata inoltre osservata nelle acque della Calabria meridionale, in Italia. Le segnalazioni di questa specie di origine atlantica, il cui areale di distribuzione è in espansione nel Mediterraneo, documentano per la prima volta la sua presenza in acque libiche e lungo le coste del bacino meridionale nonché l'estensione della sua distribuzione nel Mar Ionio occidentale.*

Parole chiave: Specie non indigene (NIS), specie di origine atlantica in espansione, specie neonative, *Enchelycore anatina*, Libia, Italia, Mar Mediterraneo

INTRODUCTION

At a global scale, the Mediterranean Sea is considered a hotspot of non-indigenous species introductions (NIS), both in terms of the number of species introduced and introduction rates (Tempesti *et al*., 2020). The deliberate or inadvertent introduction of NIS represents an essential stressor for ecosystems marine biological communities (Grosholz, 2002; Bax *et al*., 2003). NIS can exert significant ecological impacts, such as an escalation of changes in the patterns of distribution, abundance and diversity of native species (Claudet & Fraschetti, 2010) as well as modification of food web structure and energy flow (Libralato *et al*., 2002).

Concurrent with the entry of thermophilic NIS, mostly native to the Indo–Pacific region, the so-called "Lessepsian migration," the arrival of natural range-expanding thermophilic Atlantic species into the Mediterranean Basin has been well-documented in recent years (Evans *et al*., 2020). Marchini *et al*. (2015) define eastern Atlantic species as "having most likely entered the Mediterranean Sea through the Strait of Gibraltar, lacking evidence of human transport," whilst Essl *et al*. (2019) have recently proposed the term "neonatives" as an alternative designation for this class of newcomers. The distribution of these Atlantic range-expanding species is not restricted to the western half of the Mediterranean, but is increasingly spreading eastwards within the basin. Deidun *et al*. (2021a), for instance, recently documented the occurrence of nine Atlantic range-expanding species within the Malta–Sicily Channel in the central Mediterranean.

Despite a recent surge in the research effort to document the increase of NIS and neonative species within the Mediterranean, considerable knowledge gaps are still evident in a number of areas, most notably the Libyan coastal waters (Al Mabruk *et al*., 2021).

The fangtooth moray, *Enchelycore anatina* (Lowe, 1839), belongs to the family Muraenidae, which is represented in the Mediterranean by three other species, the two natives, the Mediterranean moray *Muraena helena* (Linnaeus, 1758) and the brown moray *Gymnothorax unicolor* (Delaroche, 1809), as well as a NIS of Indo-Pacific origin, the moray eel *Gymnothorax reticularis* Bloch, 1795 (Bauchot, 1986; Stern & Goren, 2013; Froese & Pauly, 2021). Another moray eel species, *Anarchias euryurus* (Lea, 1913), native to the eastern Atlantic Ocean, has been recorded from the Mediterranean, but through a single record off Nice, France, in non-recent times (Bauchot, 1986; Froese & Pauly, 2021).

The fangtooth moray *E. anatina* is a demersal inshore species living on rocky vegetated habitats, up to depths of 50 m; it reaches a maximum length of 120 cm, feeds prevalently on fishes and large invertebrates and its larvae are pelagic (Golani *et al*., 2021). This subtropical species is widely distributed in the eastern Atlantic, occupying a broad swathe extending from the Azores to the island of St. Helena (Golani *et al*., 2021). Although it is considered an Atlantic range-expanding fish species in the Mediterranean (Zenetos *et al*., 2012), it shows an atypical distribution within the basin. In fact, after being first recorded in the Mediterranean from Israeli waters in 1979 (Ben-Tuvia & Golani, 1984), the species progressively spread into the Levantine Sea (Katsanevakis *et al*., 2009; Ergüden *et al*., 2013; Iglésias & Frotté, 2015; Bariche & Fricke, 2020), the Aegean (Kalogirou, 2010 and references therein; Şenbahar & Özaydın, 2020) and the Adriatic (Lipej *et al*., 2011), and the Ionian seas as far west as the island of Malta (Guidetti *et al*., 2012; Pirkenseer, 2013; Katsanevakis *et al*., 2014; Deidun *et al*., 2015; Marletta & Lombardo, 2020). The distribution of records of *E. anatina* in the Mediterranean has been recently reviewed in detail by Marletta & Lombardo (2020). Of late, the species has also been recorded along the southern coasts of the Mediterranean, off Alexandria, Egypt (Ragheb & Rizkalla, 2020); however, this record is a dubious one as it might be a misidentification of a *M. helena* specimen. The fangtooth moray is thus unknown to date from the western basin as well as from its southern shores.

This study describes the first finding of *E. anatina* from Libyan waters, confirming that the species is spreading along the North African coasts. A further documentation of *E. anatina* along the southwestern coast of the Italian region of Calabria is also hereby reported, corroborating the species' establishment in the western Ionian waters of Italy.

MATERIAL AND METHODS

On 26 December 2020, one individual of *E. anatina* was caught by a local fisherman in Bomba Bay, west of Tobruk, eastern Libya (32.392593°N, 23.135857°E) (Fig. 1) with gillnets at approximately 20 m of depth, over a rocky seabed. The freshly-caught sample was photographed, measured and weighed in the lab, and preserved in the private collection of one of the authors (AA). In order to count the number of vertebrae, the sample was subjected to X-ray analysis.

Furthermore, a specimen of *E. anatina* was photographed during SCUBA diving on 17 July 2020 at 10 m of depth along the southwestern tip of Italy, at Saline Joniche (Reggio Calabria), Ionian Sea (37.934326°N, 15.712948°E) (Fig. 1). The seabed of the area was sandy and rocky, with *Posidonia oceanica* meadows and coralligenous assemblages.

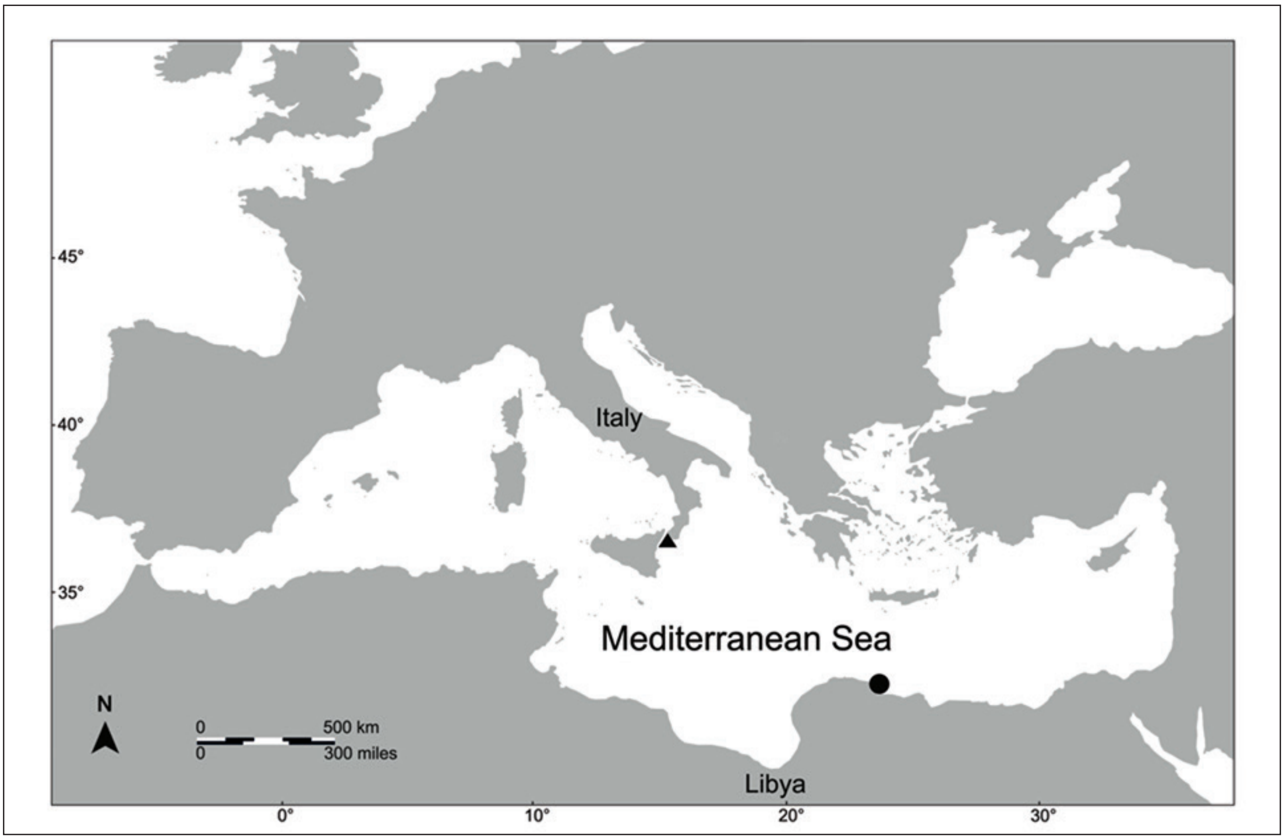


Fig. 1: Map of the Mediterranean Sea showing the locations of Bomba Bay, Libya (●) and Saline Joniche (Italy) (▲), where the *Enchelycore anatina* ***species was recorded.***
Sl. 1: Zemljevid Sredozemskega morja z označenima lokalitetama zaliva Bomba, Libija (●) in Saline Joniche (Italija) (▲), kjer je bila zabeležena vrsta *Enchelycore anatina****.***



Fig. 2: The specimen of *Enchelycore anatina* ***captured in eastern Libya [Black bar= 100 mm] (A) and its upper (B) and lower (C) jaws (Photos by A. Abdulghani).***
Sl. 2: Primerek vrste *Enchelycore anatina****, ujet v vzhodni Libiji [Črna črta = 100 mm] (A) in njena zgornja (B) in spodnja (C) čeljust (Foto: A. Abdulghani).***



Fig. 3: The specimen of* Enchelycore anatina *observed in Saline Joniche, Calabria, Italy (Photo by D. Salvatori).
Sl. 3: Primerek vrste* Enchelycore anatina*, opažen v Saline Joniche, Kalabrija, Italija (Foto: D. Salvatori).

At a depth between 10 and 15 m, vertical walls rich with ravines and cavities created a series of corridors and along one of these corridors the specimen in question was observed.

The specimens from Libya and Italy were identified as *E. anatina* (Figs. 2, 3) according to Ben-Tuvia & Golani (1984), Bauchot (1986), Böhlke & Smith (2002), Smith & Brito (2016) and Golani *et al.* (2021).

RESULTS

The captured specimen, 640 mm in length and 185 g in weight, presented a compressed and elongated body with no scales, a very long dorsal fin, its origin slightly in advance of gill openings, and an anal fin confluent with the caudal fin. Pectoral and pelvic fins absent. Head pointed with elevated occipital region (Figs. 2, 3). Anterior nostril tubular, posterior nostril oval and opening above anterior margin of eye, mouth large, its cleft extending behind eye, jaws arched, a series of fang-like teeth visible even when the mouth is closed (Figs. 2, 3). Fang-like teeth arranged in an irregular series on both side of the upper jaw and in two series on both sides of the lower jaw, smaller in the outer rows, larger in the inner ones (Fig. 2A, 2B). A total of 151 vertebrae were counted. Body colour brown with yellowish blotches, for the most part irregularly rounded, and dots, running longitudinally along the length of the fish and on fins; snout and cheeks light brown with small yellow spots; jaw pores not noticeably white (Figs. 2, 3).

The proportions of selected measurements were: body depth 5.6, head length 12.5, trunk length 43.8, tail length 56.3, snout length 2.4, eye diameter 1.0, interorbital width 1.1, and mouth cleft 6.3, all expressed as % of total length (Tab. 1).

DISCUSSION

The description of our specimens, the findings concerning the body proportions, the number of vertebrae as well as the habitat type agreed with those reported in the literature for *E. anatina* (cf. Ben-Tuvia & Golani, 1984; Smith & Brito, 2016).

A number of diagnostic characteristics distinguish the fangtooth moray from the other Muraenidae species reported in the Mediterranean. In the genus *Gymnothorax*, the jaws are not arched; the body is uniformly coloured in the native *G. unicolor* while striped with 18 dark brown bars on pale yellowish background in the Red Sea/Indo-Pacific *G. reticularis* (Bauchot, 1986; Stern & Goren, 2013). In *M. helena,* the jaws are not arched, both posterior and anterior nostrils are tubular and the body is brown with large, pale yellow spots, each of which contains smaller brown spots (Smith & Brito, 2016).

Compared to other Atlantic NIS fishes that follow a natural range expansion into the Mediterranean through the Strait of Gibraltar and further eastwards within the basin (see Evans *et al.*, 2020; Golani *et al.*, 2021), the current Mediterranean distribution of *E. anatina* appears anomalous, since, to date, it has only been recorded within the eastern and central swathes of the basin while, concurrently, its occurrence has not been reported in the western ones. The recent findings of *Ablennes hians* (Valenciennes, 1846) in the eastern and central Mediterranean (Deidun *et al.*, 2021b) are similarly reminiscent of the equally anomalous *E. anatina* distribution, but it is far too early to draw any parallels between the two species. A similar spreading pattern, on the other hand, has been observed for the heterobranch seaslug *Aplysia dactylomela* Rang, 1828, of confirmed Atlantic origin (Valdés *et al.*, 2013). In the Mediterranean, this sea hare was first recorded from the Strait of Sicily (Trainito, 2003), subsequently greatly expanding its

Tab. 1: Measurements (mm) and body proportions (as percentages of total length) of the *Enchelycore anatina* ***specimen from Libya.***
Tab. 1: Meritve (mm) in deleži telesa (v odstotkih celotne dolžine) osebka vrste *Enchelycore anatina* ***iz Libije.***

Measurements	**Size (mm)**	**%**
Total length (TL)	640.0	
Body depth	35.8	5.6
Head length	80.1	12.5
Trunk length	280.0	43.8
Tail length	360.0	56.3
Snout length	15.2	2.4
Eye diameter	6.7	1.0
Interorbital width	7.0	1.1
Mouth cleft	40.0	6.3

distribution within the Adriatic, and the central and eastern Mediterranean (Crocetta & Galil, 2012). The blue crab *Callinectes sapidus* Rathbun, 1896, a western Atlantic species, was first recorded in the Mediterranean in the late 1940s from the north Adriatic (Kampouris *et al.*, 2020), rather than from Atlantic-contiguous areas of the basin, subsequently spreading to extensive swathes of the Mediterranean, including the coasts of the eastern and central basins (Corsini-Foka *et al.*, 2021).

A number of hypotheses have been put forward to tentatively explain the unusual Mediterranean distribution of this restricted cohort of Atlantic range-expanding species. Marletta & Lombardo (2020) proposed two most feasible mechanisms which could be conveying species of eastern Atlantic origin, including *E. anatina*, directly to the eastern Mediterranean. The first involves the weakening of the Almeria–Oran front as a result of climate change and the strong Algerian Current, which flows along the North African coast in a west-east direction. The second mechanism, equally if not more feasible, involves a ballast water-mediated transport of larval stages of the same species through shipping. In fact, the prolonged pelagic stage in *E. anatina* (Guidetti *et al.*, 2012) would allow for long-distance transport of its larval forms, and the species' higher abundance in the eastern sectors of the Mediterranean basin appears to support to a greater degree this hypothesis of the shipping introduction pathway. The latter has already been postulated to explain the introduction of species of Atlantic origin to Mediterranean areas far from the western basin, as is the case with the northern brown shrimp *Penaeus aztecus* Ives, 1891 (Scannella *et al.*, 2017) and *C. sapidus* (Kampouris *et al.*, 2020).

The first catch of *Enchelycore anatina* in Libyan waters represents the first substantiated record of the species along the North African coast. The additional record of the species from the southern tip of the Italian mainland further confirms the expansion of *E. anatina* within the western Ionian Sea, to the north of previous published records of the species from the same region, described by Guidetti *et al.* (2012) and Marletta & Lombardo (2020).

The fangtooth moray is an active predator that could heavily affect native communities directly (via predator-prey interactions) and indirectly (via food web or habitat alterations) (Sala *et al.*, 2011). As a result, continuous monitoring at strategic outposts in the Mediterranean (e.g., the Strait of Sicily, Azzurro *et al.*, 2014) and *in situ* observations are fundamental in understanding how NIS and neonatives can modify ecosystem functioning and change native fish community structure (Katsanevakis *et al.*, 2014).

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PRVI ZAPIS O POJAVLJANJU KAVLJEZOBE MURENE *ENCHELYCORE ANATINA* (MURAENIDAE) IZ LIBIJSKIH VODA IN DODATNI ZAPIS ZA JUŽNO ITALIJO (ZAHODNO JONSKO MORJE)

Sami M. IBRAHIM & *Abdulrraziq A. ABDULRRAZIQ*
Department of Marine Resources, Tobruk University, Tobruk, Libya

Abdulghani ABDULGHANI
Department of Marine Resources, Omar Al-Moukhtar University, El Bayda, Libya
Marine Biology in Libya Society, El Bayda, Libya

Sara A.A. AL MABRUK
Department of General Nursing Technology, Higher institute of Science and Technology, Cyrene, Libya
Marine Biology in Libya Society, El Bayda, Libya

David SALVATORI
Via Elio Lucci 56, 00052 Cerveteri (Roma), Italy

Bruno ZAVA
Wilderness studi ambientali, via Cruillas 27, 90146 Palermo, Italy
Museo Civico di Storia Naturale di Comiso, via degli Studi 9, Comiso (RG), Italy

Maria CORSINI-FOKA
Institute of Oceanography, Hellenic Centre for Marine Research. Hydrobiological Station of Rhodes, Cos Street, 85100 Rhodes, Greece
e-mail: mcorsini@hcmr.gr

Alan DEIDUN
Department of Geosciences, University of Malta, Msida MSD 2080, Malta

POVZETEK

V zalivu Bomba, Tobruk, vzhodna Libija, je bil v zabodne mreže na približno 20 m globine ujet primerek kavljezobe murene Enchelycore anatina *(Lowe, 1839). Avtorji poročajo tudi o novi najdbi primerka te vrste iz južne Kalabrije v Italiji. Najdbe te vrste atlantskega izvora, ki se širi, potrjujejo prvi zapisi iz libijskih voda in z južnih obal Sredozemskega morja ter širitev areala vrste v zahodno Jonsko morje.*

Ključne besede: tujerodne vrste, ekspanzivne vrste atlantskega izvora, neonativne vrste, *Enchelycore anatina*, Libija, Italija, Sredozemsko morje

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MORPHOMETRIC AND MERISTIC CHARACTERISTICS OF A NEW RECORD OF BLUESPOT MULLET *CRENIMUGIL SEHELI* (PISCES: MUGILIDAE) IN EGYPTIAN MEDITERRANEAN WATERS

Rasha Ali HENEISH & *Samir Ibrahim RIZKALLA*
National Institute of Oceanography and Fisheries, NIOF, Egypt
e-mail: raheneish@gmail.com

ABSTRACT

A specimen of bluespot mullet Crenimugil seheli *(Mugilidae) was recorded for the first time in Egyptian Mediterranean waters (off Edku Lake), caught by gill net fishing gear. Eighteen morphometric characters were applied for its identification. A comparison of morphometric characters of this species with ten other species of the Mugilidae family found in the Mediterranean Sea showed that every species has different diagnostic features characterising it.*

Key words: *Crenimugil seheli,* Mugilidae, diagnostic features, Egyptian Mediterranean waters

CARATTERISTICHE MORFOMETRICHE E MERISTICHE DI UN NUOVO RITROVAMENTO DI *CRENIMUGIL SEHELI* (PISCES: MUGILIDAE) IN ACQUE MEDITERRANEE EGIZIANE

SINTESI

Un esemplare di cefalo Crenimugil seheli *(Mugilidae) è stato trovato per la prima volta nelle acque egiziane del Mediterraneo (al largo del lago Edku), catturato con reti da posta. Diciotto caratteri morfometrici sono stati applicati per la sua identificazione. Un confronto dei caratteri morfometrici di questa specie con altre dieci della famiglia Mugilidae trovate nel Mar Mediterraneo, ha evidenziato i diversi tratti diagnostici che caratterizzano le singole specie.*

Parole chiave: *Crenimugil seheli*, Mugilidae, caratteristiche diagnostiche, acque mediterranee egiziane

INTRODUCTION

The family of Mugilidae (known as mullets or grey mullets) is widely distributed in tropical and coastal areas (Johnson & Gill, 1998). Mullets live mainly in marine and brackish waters, rarely in fresh water; many species have ecological and commercial importance due to their popularity in fish farming (Bray & Hoese, 2021). Species of the family Mugilidae are characterised by two separate dorsal fins, small triangular mouths, and absence of the lateral line (Johnson & Gill, 1998).

The family of Mugilidae consists of about 72 species corresponding to 17 genera (Harrison & Senou, 1999; Nelson, 2006). Currently, ten species of Mugilidae inhabit the Mediterranean Sea, namely: *Liza carinata* Valenciennes, 1836; *Chelon aurata* Risso, 1810; *Chelon ramada* Risso, 1827; *Chelon saliens* Risso 1810; *Mugil cephalus* Linnaeus, 1758; *Oedalechilus labeo* Cuvier, 1829; *Chelon labrosus* Risso, 1827; *Liza abu* Heckel, 1843; *Mugil siouy* Basilewsky, 1855 and *Liza haematochelius* Temminck & Schlegel, 1845 (Thomson, 1997; Golani, 2000; Turan *et al.*, 2004; Minos *et al.*, 2009; Turan *et al.*, 2011). Only *Mugil cephalus* has economic value in this area (Whitfield *et al.*, 2012).

Valamugil seheli or bluespot mullet is a synonym of *Crenimugil seheli* Forsskål, 1775 (Froese & Pauly, 2021). This species is distributed from the Red Sea south to Transkei in South Africa (Smith & Smith, 1986), east to the Hawaiian and Marquesan islands, north to southern Japan, south to New Caledonia and Norfolk Island (Francis, 1993) and Tuamotu Islands (Allen & Erdmann, 2012). *Crenimugil seheli* has recently migrated from the Red Sea to Egyptian Mediterranean waters (off Edku Lake).

The objective of the current research was to identify the characteristics (morphometric and meristic) of non-native Red Sea Mugilidae species *Crenimugil seheli* in Egyptian Mediterranean waters and to corroborate this identification by comparing it with ten species of the same family in this area.

MATERIAL AND METHODS

In May 2020 one specimen of *Crenimugil seheli* (Forsskål, 1775) was captured off Edku Lake in Egyptian Mediterranean waters (40°30′31″ N, 65°30′30″ E) by gillnet together with several pelagic species: *Sardinella aurita, Sardinella maderensis, Trachurus mediterraneus* and *Engraulis encrasicolus* (Fig. 1).

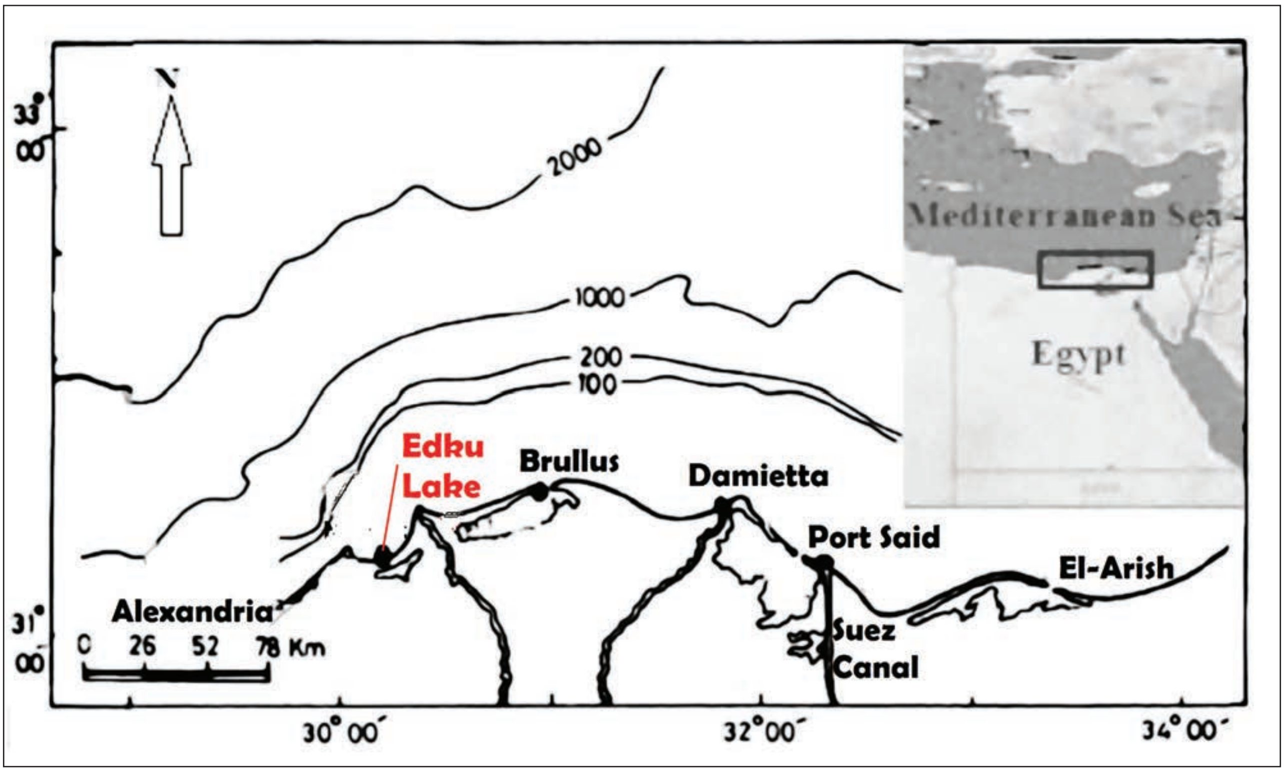


Fig. 1: Map of the sampling area (Off Edku Lake).
Sl. 1: Zemljevid obravnavanega območja (v okolici jezera Edku).

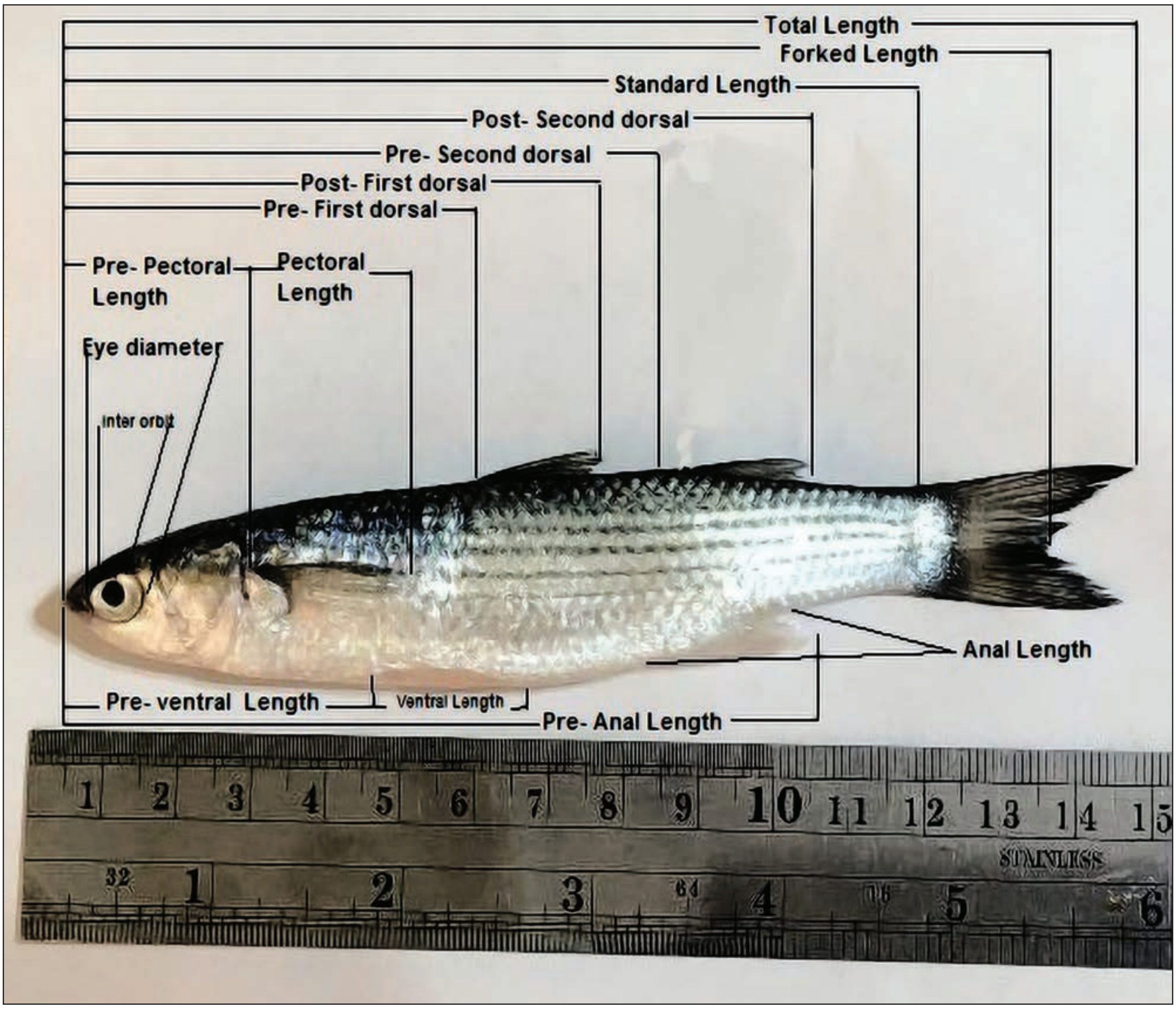


Fig. 2: Various morphometric parameters of the *Crenimugil seheli* ***the specimen caught off Edku Lake.***
Sl. 2: Razni morfometrični parametri, izmerjeni na primerku vrste *Crenimugil seheli****, ujetem blizu jezera Edku.***

Measurements to the nearest millimetre (0.01 cm) and meristic characters of the specimen are given according to Fischer & Bianchi (1984) and Froese & Pauly (2021). The following morphometric measurements are: total length (TL), forked length (FL), standard length (SL), pre-first dorsal (Pr. DI), post-first dorsal (Po. DI), pre-second dorsal (Pr. D2), post-second dorsal (Po. D2), pre-pectoral (Pr. P), pectoral length (P.L.), pre-ventral (Pr. V), pre-anal (Pr. A), post-anal (Po. A), body depth (B.D.), head length (HL), inter-orbital distance (I.O.), eye diameter (E.D.), maxillary length (Max. L.) and mandible length (Man. L.) (Fig. 2).

The morphometric index of each character is given as percentage of standard length. The I.O., E.D., Max. L and Man. L. are compared with head length (Tab. 1) according to the following formula: morphometric index = (morphometric measurement /standard length or head length) × 100.

The morphometric and meristic characters of the Mugilidae species were obtained from network data provided by (Ben-Tuvia, 1966; Fischer & Bianchi, 1984; Thomson, 1997; Harrison and Senou, 1999; Turan *et al.,* 2004; Minos *et al.,* 2009; Turan *et al.,* 2011).

RESULTS

Description

The studied specimen of bluespot mullet had a cylindrical body (Fig. 2); the first dorsal fin had 5 spines, the second dorsal fin had 8 rays, the

Tab. 1: Index range for the morphometric measurements of the *Crenimugil seheli* ***obtained off Edku Lake (Egypt).***
Tab. 1: Razpon indeksa morfometričnih meritev za primerek vrste *Crenimugil seheli****, ujetem blizu jezera Edku.***

Morphometric characters	Morphometric measurements (cm)	Index range (Morphometric measurements/ SL or HL)
TL	14.0	
FL	12.44	
SL	11.37	
Pr. D1	5.06	0.41/SL
Po. D1	6.88	0.55/SL
Pr. D2	8.06	0.65/SL
Po. D2	9.2	0.74/SL
Pr. P	2.03	0.16/SL
P. L.	2.74	0.22/SL
Pr. V.	4.13	0.33/SL
Pr. A.	7.77	0.62/SL
Po. A.	9.01	0.72/SL
B. D.	2.23	0.18/SL
HL	3.24	0.26/SL
E. D.	0.05	0.02/HL
IO.	0.74	0.27/HL
Max. L.	0.87	0.32/HL
Man. L.	0.92	0.34/HL
Meristic Characters	D1: V ; D2: 9; P:15; V: I+ 5 ; A: III+9	
Total Weight (g)		15

pectoral fin 15 rays, the ventral fin one spine and 5 rays, while the anal fin had 3 spines followed by 9 rays.

The pre-first dorsal fin measured about 55% SL, and pectoral fin 16% SL. The second dorsal fin (65% SL) was situated on nearly the same vertical line with the anal fin (62% SL). The head wide and dorsally flattened, with a length of about 26% SL. Fatty adipose tissue around the eye. Thin lips, the lower one forming a double synphorial knob. Teeth fine and well-spaced. Pectoral fin large, ending before the vertical line of the first dorsal fin origin and representing 85% H.L. Pectoral axillary scale about 38% of pectoral fin length (Fig. 3).

Body greenish blue on the back, silvery below. Upper lobe of the caudal fin dark blue. Upper rows of scales with dusky spots forming indistinct bands along the body. Dark blue spot dorsally at the origin of pectoral fin.

DISCUSSION

Biometric characters (morphometric measurements and meristic counts) are a vital tool for fish identification (Heneish & Rizkalla, 2021). Our present study concentrated on the use of these characters to identify and confirm the presence of *C. seheli* in Egyptian Mediterranean waters (off Edku Lake).

Rather than on morphological characters, previous studies on bluespot mullet focused on aspects such as food and feeding in Mangalore in Indian waters (Gangadhara, 1990); reproductive biology in farm-raised fish in the Suez Canal, Egypt (El-Halfawy, 2004); reproductive biology of this species in Suda-

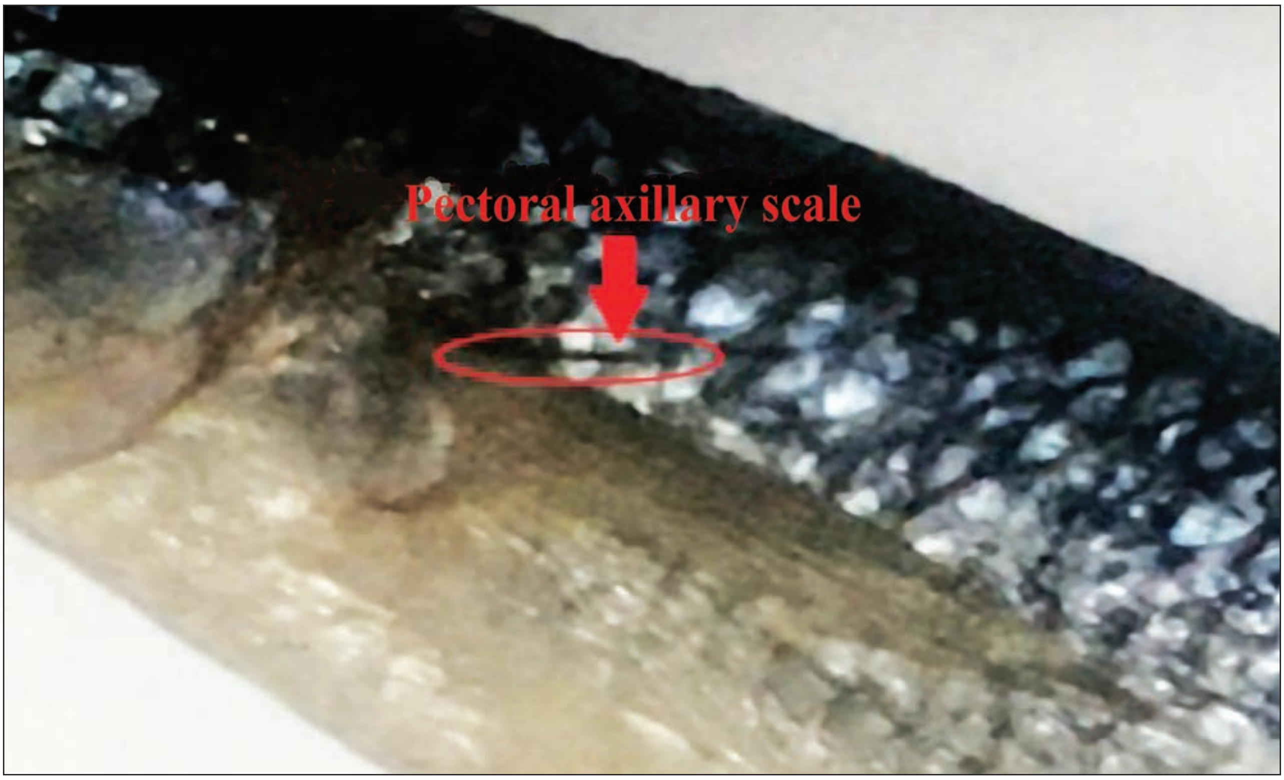


Fig. 3: Pectoral axillary scale of** Crenimugil seheli**.
Sl. 3: Prsna aksilarna luska pri vrsti** Crenimugil seheli**.

nese waters of the Red Sea (Mokhtar *et al.,* 2015); fish farming in the Suez (Egypt), as this species is considered as one of the most suitable for fish farming (Khalil *et al.,* 2016). Recently, Abu Almaaty *et al.* (2020) studied the genetic variation between four close Mugilidae species, including *L. seheli*, obtained from Port Said (Egyptian Mediterranean waters)

A comparison between the morphometric characters stated in the present study of *C. seheli* from Egyptian Mediterranean waters off Edku Lake with those provided by Fischer & Bianchi (1984) for *Valamugil seheli* of the Indian Ocean indicates a close agreement in: head length, position of second dorsal fin, rays and fins, adipose eyelid, pectoral fin length, pectoral axillary scale, and colour of the body. The two species have the same species identification (*seheli*), but differ in the genus, *Crenimugil* in the former and *Valamugil* in the latter according to Nelson (2006), who stated that *C. seheli* is a senior valid name among 26 non-valid synonyms for *Valamugil seheli*. So, the correct name of the new species in Egyptian Mediterranean waters recorded off Edku Lake is *C. seheli*.

Appendix 1 presents a comparison between the newly recorded species of *C. seheli* from the present study and ten species of the family Mugilidae in the Mediterranean Sea showing that every species has different diagnostic features characterising it.

The recorded non-native Red Sea species *C. seheli* is often mistaken for *Liza carinata*, as they are difficult to be tell apart in the fish market. The keeled mullet *L. carinata*, locally known as “Sehlia,” has migrated from the Red Sea through the Suez Canal and colonised the Mediterranean Sea (El-Ganainy *et al.,* 2014 and Mehanna *et al.,* 2019). As evidenced in Appendix 1, the two species can be distinguished by certain characters: the head length in *L. carinata* is larger than in *C. seheli*; the position of the second dorsal fin nearly on the same vertical line with the anal fin in *C. seheli*, and situated behind it in *L. carinata*; in *C. seheli* the fatty adipose tissue forms a rim around the eye, whereas in *L. carinata* it almost covers the iris; pectoral axillary scale and rows of upper scales with dusty spots present in *C. seheli*, but not in *L. carinata*.

In conclusion, the Red Sea *C. seheli* is a new non-native Mugil species in Egyptian Mediterranean Sea waters (off Edku Lake); more studies should be conducted to follow up on its distribution and fishery.

Appendix 1: Comparison between the *Crenimugil seheli* ***of the present study and other Mugilidae species in the Mediterranean Sea using morphometric and meristic characters.***
Priloga 1: Primerjava morfometričnih in merističnih znakov, dobljenih za primerek vrste *Crenimugil seheli* ***v pričujoči raziskavi z znaki drugih desetih vrst cipljev, ki se pojavljajo v Sredozemskem morju.***

Species / Caracters	***Crenimugil seheli*** **(present study)**	***Liza carinata***	***Mugil cephalus***	***Chelon aurata***	***Chelon ramada***	***Chelon saliens***	***Chelon labrosus***	***Oedalechilus labeo***	***Liza abu***	***Mugil soiuy***	***Liza haematocheilus***
Head Length	26% SL	28- 30% SL	Broad	Broad	Short & flattened	---	---	Broad	Narrow	Pointed & flattened on top	Small head pointed & flattened dorsally
(IO) and width of mouth	0.27% H. L.	Width equal width of mouth	More than width of mouth	Equal width of mouth	Equal width of mouth	Equal width of mouth	Greater than mouth cleft	Equal mouth cleft	Flat with bulky scale	---	---
Second dorsal fin	On the same line with Anal fin	Anterior quarter of anal fin	---	---	---	---	---	---	---	Behind vertical origin of anal fin	---
Adipose eye lid	Form a rim around eye	Well-developed covers the iris	Well developed	Rudiment	Poorly developed	Poorly developed	Present	Rudiment	Absent	Cover small part of iris	A yellow iris and six pyloric caeca of approximately equal length
Pectoral fin	85% of H. L.	66- 69% of H. L.	---	---	---	---	---	---	End at the same vertical level of the dorsal fin begins	Short less than 25% HL	Short pectoral fin
Pectoral axillary scale	38% of P. L.	Absent	Absent	Absent	Absent	Absent	---	---	Less than 1/3 fin length	Reaching half	Absent
Upper lip	---	Thin, its height smaller than the diameter of pupil & corner of the mouth to nearly below the front of the eye	Without papillae		Thin and less than eye diameter	Thin and less than eye diameter	Deep, equal 1/2 eye diameter with 1-3 raw of papillary on lower lip	Deeper than eye diameter and rudiment	thin obvious	without tubercles and papillae	---
Maxilla	0.32% H. L.	---	---	---	---	---	---	---	Curved down at corner of mouth	Curved down at corner of mouth	---
Lower lip	0.34% H. L.	---	---	---	---	---	---	---		Large symphysial knod at front	---
Colour	Upper rows of scale have dusky spots. The upper lobe of caudal fin has dark blue tip	Black grey or blue	Dark longitudinal strips with dark axillary blotch	Golden batch on operculum	Strips along scales rows. Black axillary spots at Pectoral fin base	Back blue or grey	Dark longitudinal raw along the body and no dark axillary blotch	Grey blue, longitudinal golden strips along body are present	Darkish color dorsally and lighter ventrally; blackish margin of dorsal and caudal fins	Yellowish body grey	Emarginated to slight forked caudal fin and large scales, these scales and the head shape resemble a carb
Meristic characters	D1: V ; D2: 9; V: I+ 5; A: III+9;P:15	D1:IV; D2::1+7; A:III+7; V: 1+5; P: 15	D1:IV; D2::1+8; A:III+8- 9; V: 1+5; P: 17	D1:IV; D2::1+8; A:III+8- 9; V: 1+5; P: 16	D1:IV; D2::1+7- 8; A:III+8- 9; V: 1+5; P: 16- 17	D1:IV; D2::1+7; A:III+7- 8; V: 1+5; P: 16	D1:IV; D2::1+8; A:III+8-9; V: 1+5 P: 17	D1:IV; D2::1+8; A:III+8-10; V: 1+5 P: 16- 17	D1:IV; D2::1+7- 8; A:III+8-; V: 1+5 P: 11- 12	D1:IV; D2::1+8; A:III+8-9; V: 1+5 P: 16- 17	---

NOVI ZAPIS O POJAVLJANJU VRSTE *CRENIMUGIL SEHELI* (PISCES: MUGILIDAE) V EGIPTOVSKIH SREDOZEMSKIH VODAH IN NJENE MORFOMETRIČNE IN MERISTIČNE ZNAČILNOSTI

Rasha ALI HENEISH & *Samir Ibrahim RIZKALLA*
National Institute of Oceanography and Fisheries, NIOF, Egypt
e-mail: raheneish@gmail.com

POVZETEK

Avtorja poročata o prvem zapisu o pojavljanju primerka vrste ciplja Crenimugil seheli *(Mugilidae) v egiptovskih sredozemskih vodah (blizu jezera Edku), ujetega v zabodno mrežo. Primerek sta določila na podlagi 18 merističnih znakov. Primerjava morfometričnih znakov te vrste z desetimi drugimi vrstami iz družine cipljev (Mugilidae), ki živijo v Sredozemlju, je pokazala, da vsako vrsto opredeljujejo različni diagnostični znaki.*

Ključne besede: *Crenimugil seheli,* Mugilidae, diagnostični znaki, egiptovske sredozemske vode

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HEAVY METAL CONCENTRATIONS IN TISSUES OF *SIGANUS RIVULATUS* (SIGANIDAE) FROM THE SYRIAN COAST (EASTERN MEDITERRANEAN SEA)

Yana SOLIMAN & Adib SAAD
Marine Sciemces Laboratory, Faculty of Agriculture, Tishreen University, Lattakia, Syria

Vienna HAMMOUD
Department of Zoology, Faculty of Sciences, Tartus University, Syria

Christian CAPAPÉ
Laboratoire d'Ichtyologie, Université de Montpellier, 34095 Montpellier cedex 5, France
e-mail: capape@univ-monpt2.fr

ABSTRACT

Concentrations of heavy metals such as copper (Cu) and lead (Pb) were measured in the liver and muscle tissues of marbled spinefoot Siganus rivulatus *collected from three main landing areas along the Syrian coast. Muscle tissues always accumulate the lowest concentrations of all metals. In most studied fish, the liver is the target organ for Cu and Pb accumulation. The concentrations of copper in muscle tissues ranged between 0.392 and 0.788 µg/g, in liver between 17.11 and 45.77, lead in muscle tissues from 0.0142 to 0.022 µg/g, and in liver from 0.1 to 0.231 µg/g. The heavy metal with the highest average level recorded in fish is Cu, followed by Cd and Pb. The concentrations of metals in the present fish muscle tissues fell within international legal limits; the fish were thus safe for human consumption.*

Key words: heavy metals, pollution, liver, muscle tissues, *Siganus rivulatus*, Syrian coast

CONCENTRAZIONI DI METALLI PESANTI NEI TESSUTI DI *SIGANUS RIVULATUS* (SIGANIDAE) DALLA COSTA SIRIANA (MEDITERRANEO ORIENTALE)

SINTESI

Le concentrazioni di metalli pesanti come il rame (Cu) e il piombo (Pb) sono state misurate nel fegato e nei tessuti muscolari del pesce coniglio Siganus rivulatus*, ottenuto in tre zone principali di sbarco lungo la costa siriana. I tessuti muscolari accumulano sempre le concentrazioni più basse di tutti i metalli. Nella maggior parte dei pesci studiati, il fegato è l'organo bersaglio per l'accumulo di Cu e Pb. Le concentrazioni di rame nei tessuti muscolari variavano da 0,392 e 0,788 µg/g, nel fegato da 17,11 a 45,77 µg/g, mentre il piombo nei tessuti muscolari da 0,0142 a 0,022 µg/g, e nel fegato da 0,1 a 0,231 µg/g. Il metallo pesante con il più alto livello medio registrato nei pesci studiati è Cu, seguito da Cd e Pb. Le concentrazioni di metalli nei tessuti muscolari dei pesci analizzati rientravano nei limiti legali internazionali; i pesci erano quindi sicuri per il consumo umano.*

Parole chiave: metalli pesanti, inquinamento, fegato, tessuti muscolari, *Siganus rivulatus*, costa siriana

INTRODUCTION

Two species of the genus *Siganus* Forsskål, 1775 occur in the Syrian marine waters, dusky spinefoot *Siganus luridus* (Rüppell, 1829) and marbled spinefoot *S. rivulatus* Forsskål & Niebuhr, 1775 following Saad (2005) and Ali (2018). These two species represent 9% of the total catch by artisanal fisheries and constitute a large part of the total seafood production from Syria (Saad *et al.*, 2016).

Fishes, as a source of protein for local population, are usually at the end of the food chain and considered to be an important zoological group in transferring metals to humans (Aytekin *et al.*, 2019). Bioaccumulation of heavy metals in fish tissues has been the object of previous studies (Saad & Hammoud, 2007; Turan *et al.,* 2009; Abdallah, 2013; Soliman *et al.*, 2021), of which Khaled (2004) and El-Moselhy *et al.* (2014) also studied the concentrations of heavy metals in different tissues removed from *Siganus rivulatus*.

Similarly, the main goal of the present study was to assess the concentrations of heavy metals such as Pb, Cu, and Cd in muscles and liver of *S. rivulatus* caught by commercial fisheries from three areas located on the coast of Syria.

MATERIAL AND METHODS

Study area

The study was conducted between February 2019 and January 2020 on three sites in the Syrian coast (Fig. 1). The first (T1) is located relatively far from any source of industrial pollution (34°59′46″ N and 35°53′21″ E). The second site (T2) was chosen based on its proximity to a thermal power station (35°10′11″ N and 35°55′36″ E). The third site (T3) is an area for the sewage disposal (34°53′09″ N and 35°52′57″ E).

Fish sampling and analysis

A total of 24 specimens were collected and analyzed. They were immediately placed on ice in an isolated box, transported immediately to the laboratory, and then stored at –20° C until analyzed. The total length of each specimen was recorded to the nearest millimetre and total body weight to the nearest decigram. The liver and a sufficient amount of muscle tissue were removed. The wet digestion method was used for analysis of heavy metals (see Soliman *et al.*, 2021). Samples were transferred into digestion flasks and treated with 5 ml HNO_3 (ultrapure, Merck) on a hot plate until the colour turned to light yellow, nearly white. After this process the samples were transferred to 25 ml flasks and double distilled water was added up to the mark 25 ml. The solution was filtered through filter papers. After digestion, all the samples were analysed for trace metal (Pb, Cu, and Cd) concentrations using computer controlled Atomic Absorption Spectrophotometer (Spectra AA 220). Accuracy of the employed method was tested against reference material.

Statistical analysis

Statistical differences between averages of metal concentrations from different sites were evaluated using one-way ANOVA. The seasonal differences in concentrations were analyzed using Student's *t*-test.

RESULTS AND DISCUSSION

Accumulation of metals in organs

Concentrations of heavy metals such as copper (Cu) and lead (Pb) in the livers and muscles of specimens collected from the 3 areas (see Fig. 1) are reported in Table 1. They are significantly higher in

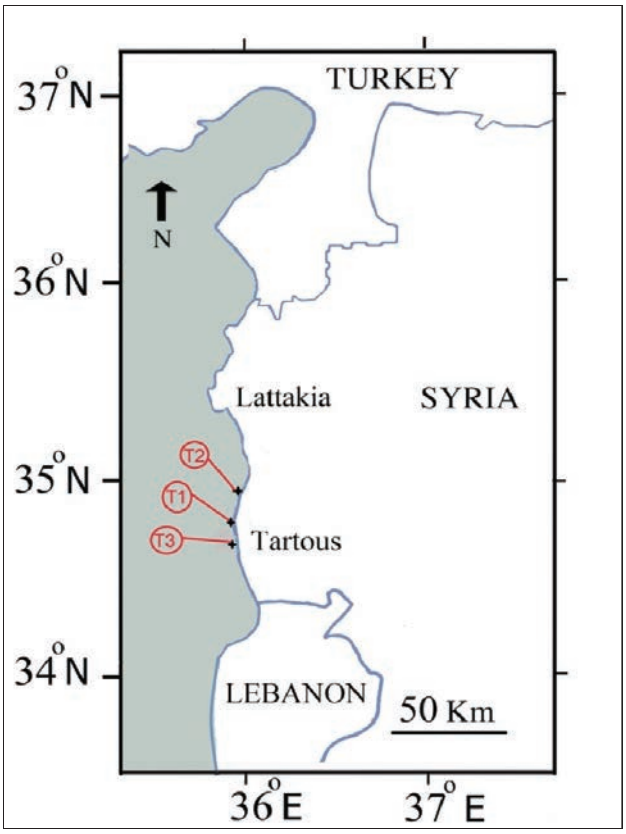


Fig. 1: Map indicating the sampling sites in the area of Tartous in the Syrian coast: T1: Off Basira, T2: Off Baniyas, T3: Off Tartous.
Sl. 1: Zemljevid z označenimi vzorčevalnimi postajami na območju Tartousa na sirski obali: T1: Basira, T2: Baniyas, T3: Tartous.

Tab. 1: Average concentrations of heavy metals (µg/g wet wt) in various tissues of* Siganus rivulatus *collected from the Syrian coast. Letters a, b, c within each column indicate significant differences among sites (ANOVA p < 0.05).
Tab. 1: Povprečne koncentracije težkih kovin (µg/g mokre mase) v različnih tkivih marmoriranih morskih kuncev (*Siganus rivulatus*), ujetih ob sirski obali. Črke a, b, c v vsakem stolpcu označujejo statistično značilne razlike med mesti (ANOVA p < 0,05).

Tissue	Site	Cu (µg/g) Mean ± SD	Pb (µg/g) Mean ± SD
Muscles	T1	a 0.10 ± 0.392	0.01425± 0.001 a
	T2	b 0.10± 0.730	0.022 ± 0.002 c
	T3	b 0.13± 0.788	0.0192 ± 0.002 b
		Cv = 9% Lsd = 0.061	Cv = 9% Lsd =0.001
Liver	T1	a 6.45 ± 17.11	a 0.022 ± 0.1
	T2	c 5.85 ± 58.56	b 0.033 0 ± 0.207
	T3	b 5.94± 45.77	0.231 ± 0.035 b
		Cv = 5.8% Lsd =3.042	C v=1 2.9% Lsd= 0.033

the livers, due to the fact that this organ plays a more important role in the metabolism of fishes (Canli & Atli, 2003; Tepe *et al.*, 2008). Additionally, Kamaruzzaman & Jalal (2008) noted that accumulations of Cu in liver are probably owed to the fact that it plays a physiological role in the metabolism of fishes. Conversely, Pb is non-essential in biochemical processes (Ekong *et al.,* 2006).

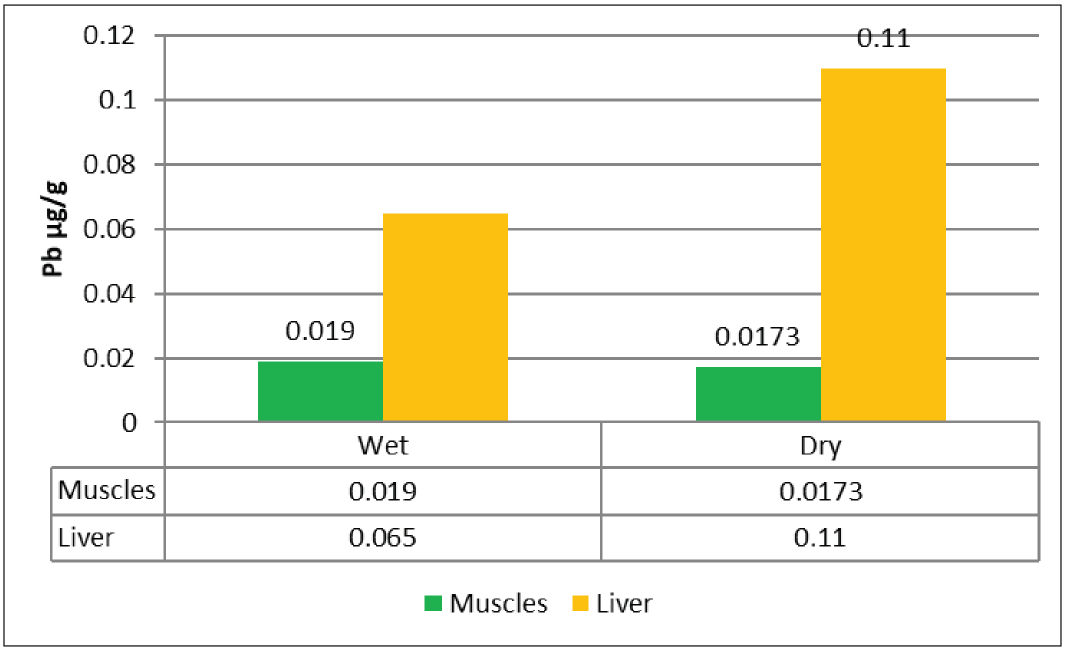


Fig. 2. Changes in Cu concentrations in* Siganus rivulatus *according to season (Wet: winter and spring; Dry: summer and autumn).
Sl. 2: Spremembe v vsebnosti Cu pri vrsti* Siganus rivulatus *glede na sezono (Wet: zima in pomlad; Dry: poletje in jesen).

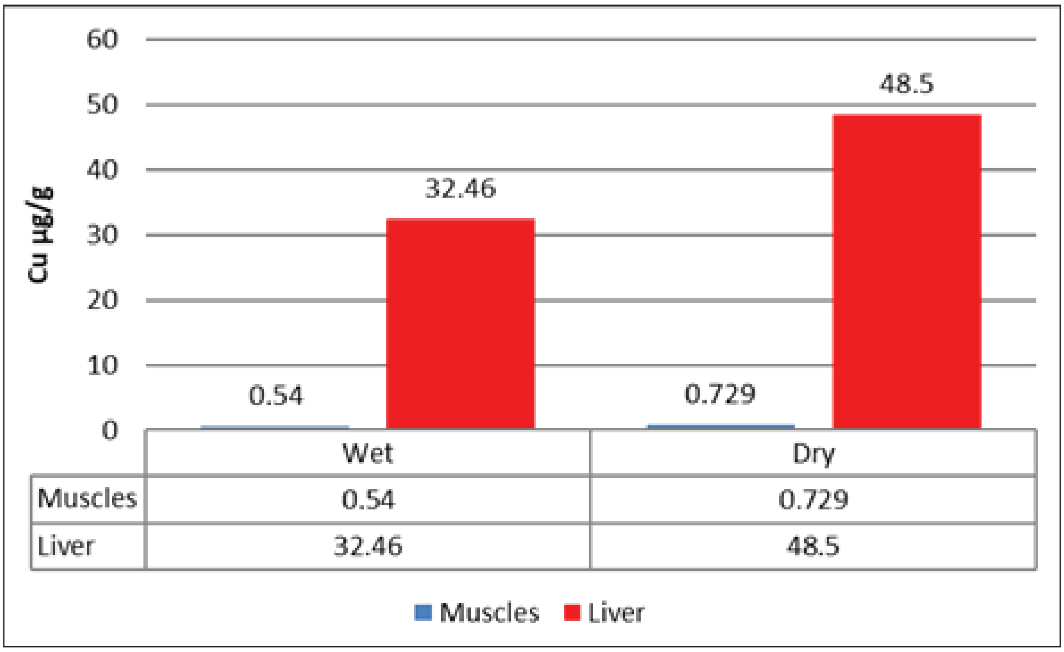


Fig. 3. Changes in Pb concentrations in** Siganus rivulatus **according to season (Wet: winter and spring; Dry: summer and autumn).
Sl. 3: Spremembe v vsebnosti Cu pri vrsti** Siganus rivulatus **glede na sezono (Wet: zima in pomlad; Dry: poletje in jesen).

S. rivulatus displayed low concentrations of Cu and Pb in muscles, indicating that these organs do not constitute an active site for biotransformation and accumulation of heavy metals (Mohamed, 2008). Similar patterns were reported for 2 fish species, *S. rivulatus* and *Sargus sargus*, collected off Alexandria, in the Mediterranean coast of Egypt (Khaled, 2004).

The highest concentrations of Cu accumulation in the liver (58.56 ± 5.85 µg/g wet wt) were found in the *S. rivulatus* from (T2), the lowest (17.11 ± 6.45 µg/g wet wt) in those from (T1). Concentrations of Cu in muscles ranged from 0.392± 0.10 (T1) to 0.788 ± 0.130 µg/g wet wt (T3). Such values are probably due to the fact that (T1) is less affected by anthropogenic pollutants than the two other sites. Copper concentrations in muscle tissues found in this study were lower than those reported from Alexandria (Khaled, 2004) and the Red Sea (El-Moselhy *et al.*, 2014) in Egypt. Concentrations of Pb in liver ranged from 0.1 ± 0.022 (T1) to 0.231 ± 0.30 µg/g wet wt (T3), while concentrations of Pb in muscles ranged from 0.01425 ± 0.001 (T1) to 0.022 ± 0.002 µg/g wet wt (T2). Lead concentrations in muscle tissues found in this study were lower than those from Alexandria (Khaled, 2004), an area that is more exposed to anthropogenic activities.

Seasonal variations in concentrations of metals

There were significant differences in the Cu and Pb accumulated in the white muscles and livers of S. *rivulatus* depending on the season – dry or rainy – when the sampled specimens were collected (Fig. 2).

Mean Cu concentrations in the muscles of the fish from the Syrian coast ranged between 0.54 µg/g in the rainy season and 0.729 µg/g in the dry season, and in the liver between 32.46 during the rainy season and 48.50 µg/g during the dry season (Fig. 2). The levels of Cu in the muscle and liver tissues were significantly higher in the dry season compared to the rainy season (t-value = -8.48, 3.27; $P < 0.001$).

Mean Pb concentrations in white muscle and liver tissues of *S. rivulatus* showed significant differences between seasons (Fig. 3), ranging from 0.017 µg/g to 0.019 µg/g (t-value = 11.18.; $P < 0.001$).

Mean Pb concentrations in the liver ranged from 0.065 in the rainy and 0.11 µg/g in the dry season (Fig. 3). Pb levels in muscle tissues differed between seasons (t-value = 4.53.; $P = 0.004$) (Fig. 3). The accumulation of metals in white muscle and liver tissues increased in summer and spring compared to other seasons. Such a pattern may be related to the fact that human activities increase during these

seasons (Hegazi *et al.*, 2015). It could also be due to the rate of metabolism as a consequence of higher temperatures of the sea (Jakimska *et al.,* 2011).

El-Moselhy (2003) noted that seasonal variations in the concentration of heavy metals in marine organisms were also affected by other factors, such as wind, current regimes, monthly salinity variation, as well as the impact of various pollution sources.

The results for *S. rivulatus* showed that metal accumulation during the dry season was significantly higher than during the rainy season, and that Cu and Pb accumulations were higher in the liver than in the muscles (Figs. 2 and 3). Shreadah *et al.*, 2016 also observed increase in Pb concentrations during the summer, which could be a result of human impact and traffic increase. Similar summer increases in metal levels were observed in fish from the coasts of Iskenderun Gulf, Turkey (Aytekin *et al.*, 2019).

Health risk assessment for heavy metal intake through fish consumption

In this study, the essential heavy metal Cu detected in the livers was above the limits for fish consumption recommended by the Food and Agriculture Organization/World Health Organization (FAO/WHO) and the European Union (EU). Conversely, the non-essential metal Pb in the liver was below the limits for fish consumption recommended by WHO and FAO and was slightly higher than the levels recommended by the European Union (EU). Muscles are the most important part of the fish to be eaten by humans and reflect the concentrations of metals in the water where the fish species lives (Tepa *et al.,* 2008; Can *et al.*, 2020).

In polluted aquatic habitats the concentration of metals in fish muscles can exceed the permissible limits for human consumption and imply severe health threats (Shreadah *et al.*, 2016; Yilmaz *et al.,* 2017; Yilmaz *et al.,* 2018). To assess the public health risk from the consumption of fish from the Syrian coast we compared the levels of metal in muscles from the current study (Tab. 1) against existing standards for human consumption established by many different health organizations (Tab. 2).

Tab. 2: Maximum permissible limit (MPL) of heavy metals in fish muscles (mg/g wet wt) according to international standards.

Tab. 2: Največja dovoljena meja (MPL) vsebnosti težkih kovin v ribjih mišicah (mg/g mokre mase) po mednarodnih standardih.

References	Metals	
	Cu (µg/g)	**Pb (µg/g)**
FAO (1983)	30	0.5
FAO/WHO (1989)	30	0.5
WHO (1989)	30	2
European community		0.2

The mean levels of Cu and Pb in the muscle tissues of *S. rivulatus* were 0.636 µg/g and 0.0185 µg/g, respectively. Similar results were recorded by Khaled (2004) in *S. rivulatus* from Alexandria, Egypt, where the mean Cu and Pb levels ranged between 1.372–1.804 µg/g and 0.182–0.876 µg/g, respectively. El-Moselhy *et al.* (2014) established the mean levels in *S. rivulatus* from the Red Sea, Egypt at 0.35 µg/g for Cu and 0.44 µg/g for Pb. The same authors suggested that these values were within safe limits for human consumption. According to the results, the fish examined in our study were also within the limits and therefore safe for human consumption. Although, currently, the levels of heavy metals in fish in these regions do not exceed the limits, that may change in the future, depending on the anthropogenic sources from agriculture and industrial development.

VSEBNOST TEŽKIH KOVIN V TKIVIH MARMORIRANEGA MORSKEGA KUNCA *SIGANUS RIVULATUS* (SIGANIDAE) IZ SIRSKE OBALE (VZHODNO SREDOZEMSKO MORJE)

Yana SOLIMAN & Adib SAAD
Marine Sciemces Laboratory, Faculty of Agriculture, Tishreen University, Lattakia, Syria

Vienna HAMMOUD
Department of Zoology, Faculty of Sciences, Tartus University, Syria

Christian CAPAPÉ
Laboratoire d'Ichtyologie, Université de Montpellier, 34095 Montpellier cedex 5, France
e-mail: capape@univ-monpt2.fr

POVZETEK

Koncentracije težkih kovin, kot sta baker (Cu) in svinec (Pb), so bile izmerjene v jetrih in mišičnih tkivih marmoriranih morskih kuncev Siganus rivulatus*, ujetih blizu treh glavnih pristanišč ob sirski obali. Mišična tkiva vedno kopičijo najnižje koncentracije vseh kovin. Pri večini raziskanih rib so jetra ciljni organ za ugotavljanja kopičenja Cu in Pb. Koncentracije bakra v mišičnih tkivih so se gibale med 0,392 in 0,788 µg/g in v jetrih med 17,11 in 45,77. Koncentracije svinca v mišičnih tkivih so se gibale od 0,0142 do 0,022 µg/g, v jetrih pa od 0,1 do 0,231 µg/g. Težka kovina z najvišjo povprečno vrednostjo, zabeleženo v ribah, je Cu, sledita Cd in Pb. Koncentracije kovin v ribjih mišičnih tkivih so bile v mejah standardov mednarodnega prava; ribe so bile tako varne za prehrano ljudi.*

Ključne besede: težke kovine, onesnaževanje, jetra, mišična tkiva, *Siganus rivulatus*, sirska obala

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LENGTH-WEIGHT RELATIONS AND GROWTH ESTIMATES IN THE BLUE SHARK, *PRIONACE GLAUCA*, FROM THE CENTRAL ATLANTIC COAST OF MOROCCO

Jihade ALAHYENE & Brahim CHIAHOU
Chouaib Doukkali University, Faculty of Sciences, Department of Biology, El Jadida, Morocco
e-mail: jihad.20081@hotmail.com

Hammou EL HABOUZ & Abdelbasset BEN-BANI
National Fisheries Research Institute (INRH), Agadir, Morocco

ABSTRACT

The blue shark, Prionace glauca*, is widely distributed in the Mediterranean and the Atlantic Ocean. The present study proposes a management plan for this species based on biological data, including length-weight relationships and other growth parameters, morphometry, and longevity. Regular biological sampling of the blue shark was carried out during a period of 24 months (October 2017–October 2019). Specimens were collected from the artisanal fishing boats operating off the Central Atlantic coast of Morocco, especially in the region of Sidi Ifni, and in seasonal acoustic surveys. A total of 7224 individuals were examined, including 3704 females and 3520 males. The total length (TL) ranged from 48 cm to 340 cm in females and 55 cm to 350 cm in males. Both sexes had a length-weight relationship of* $W(t) = 10^{-6} * TL^{3.4283}$*, indicating significant major allometry. The von Bertalanffy parameters for both sexes combined were* $L_{\infty} = 413.59$ *cm,* $k = 0.20$ *year*$^{-1}$*, and* $t_0 = 0.76$*. Longevity (*t_{max}*) was more than 17 years for males and females.*

Key words: *Prionace glauca*, morphometry, length-weight, Von Bertalanffy parameters, longevity

RELAZIONI LUNGHEZZA-PESO E STIME DI CRESCITA NELLA VERDESCA, *PRIONACE GLAUCA*, LUNGO LA COSTA ATLANTICA CENTRALE DEL MAROCCO

SINTESI

La verdesca, Prionace glauca*, è ampiamente distribuita nell'Oceano Atlantico e nel Mediterraneo. Il presente studio propone un piano di gestione per questa specie basato su dati biologici, tra cui il rapporto lunghezza-peso e altri parametri di crescita, morfometria e longevità. Il campionamento biologico regolare della verdesca è stato effettuato per un periodo di 24 mesi (ottobre 2017-ottobre 2019). Gli esemplari sono stati raccolti dai pescherecci artigianali che operano al largo della costa atlantica centrale del Marocco, in particolare nella regione di Sidi Ifni, e durante le indagini acustiche stagionali. In totale sono stati esaminati 7224 individui, di cui 3704 femmine e 3520 maschi. La lunghezza totale (TL) variava da 48 cm a 340 cm nelle femmine e da 55 cm a 350 cm nei maschi. Entrambi i sessi presentavano una relazione lunghezza-peso pari a* $W(t) = 10^{-6} * TL^{3,4283}$*, indicando una significativa maggiore allometria. I parametri di von Bertalanffy per entrambi i sessi combinati erano* $L\infty = 413,59$ *cm,* $k = 0,20$ *anno*$^{-1}$ *e* $t_0 = 0,76$*. La longevità (tmax) era superiore ai 17 anni per entrambi ii sessi.*

Parole chiave: *Prionace glauca*, morfometria, lunghezza-peso, parametri di Von Bertalanffy, longevità

INTRODUCTION

The blue shark, *Prionace glauca* (Linnaeus, 1758), is an oceanic-epipelagic shark species in the Carcharhinidae family and among the most abundant and fished elasmobranchs in the world (Nakano & Stevens, 2008). It is classified by the IUCN Red List of Threatened Species as near threatened worldwide (Rigby *et al*., 2019) and critically endangered in the Mediterranean Sea (Serena *et al*., 2021). *P. glauca* is an oceanic and circumglobal shark inhabiting temperate and tropical waters and probably the widest ranging chondrichthyan, with his distribution range also extending into the Mediterranean Sea (Ebert & Stehmann, 2013). Blue shark's movements are strongly influenced by water temperature (Vas, 1990), and this species undergoes seasonal latitudinal migrations on both sides of the North Atlantic (Stevens, 1976; Casey, 1985; Silva *et al*., 1996), the South Atlantic (Hazin et *al*., 1991) and the North Pacific (Nakano, 1994). It is found in the same waters as other pelagic sharks and tuna species (*Isurus oxyrinchus, Xiphias gladius, Thunnus obesus*, and *T. thynnus*) (Cortés *et al*., 2010).

In Morocco, the blue shark is exploited by coastal and freezer longliners, as well as by the artisanal fleets operating along the Moroccan coast. The fishing gear used in the targeted fishery is mainly longline and, to a minor extent, the so-called "bonitard" drifting gill net. The catch of artisanal boats that target sharks in the study area usually consists of about 85% blue sharks, 13% mako sharks, and 2% other species. According to fishing crews and wholesalers at the Sidi Ifni port, after the first vending for local consumption at the fish market in the port of Sidi Ifni, these sharks are shipped outside the region to other cities in Morocco. It is mainly sold in major markets. In addition, Morocco is an exporter of shark fins to European and Asian countries (Okes & Sant, 2019). The lack of basic scientific data on the blue shark in Morocco hampers the management of this species. Scientific monitoring was initiated for the better preservation of this shark. Moreover, except for Hamdi's study on the blue shark's growth, few elements are available in Morocco. Stock assessment depends on detailed size, age, and growth data (ICCAT, 2007). In the present study, authors report on the length-weight relationship (LWR) and growth parameters of *Prionace glauca*, based on a remarkable number of individuals, either captured in targeted fishery or captured as bycatch off the Central Atlantic coast of Morocco.

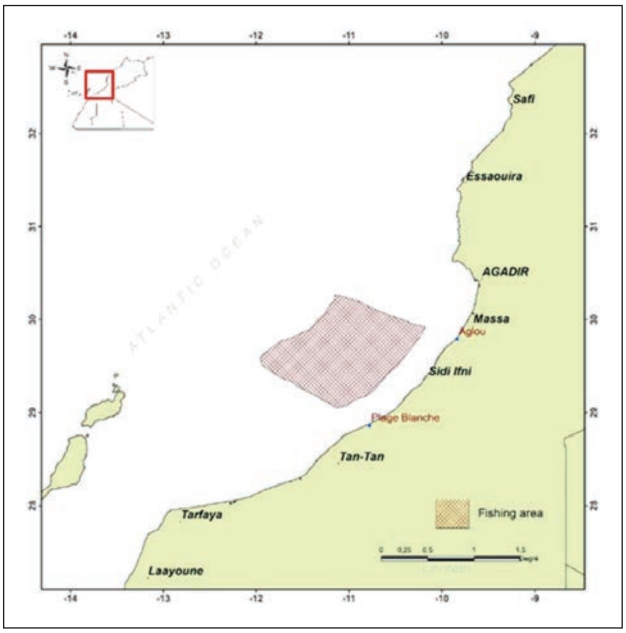


Fig. 1: Blue shark landing area at the port of Sidi Ifni.
Sl. 1: Območje iztovarjanja sinjega morskega psa v pristanišču Sidi Ifni.

MATERIAL AND METHODS

Study area and sampling

The samples and measurements were taken at the Sidi Ifni port, located on the Central Atlantic coast of Morocco (latitude: 29°21'N - longitude: 10°11'W) about 170 km south of Agadir. The artisanal fishing area was between 10°W and 12°W longitude, and between 29°N and 31°N latitude, and was bound to the north by the coast of Aglou and to the south by a beach commonly known as Plage Blanche (Fig. 1). This area has a subtropical climate with surface water temperatures varying from 14 to 22.1°C. A total of 7224 blue sharks (3704 females and 3520 males) were sampled during a period of 24 months (October 2017–October 2019) from the artisanal fishing boats operating in the area, and in seasonal acoustic surveys carried out in spring (mid-March to May) and autumn (September to October) by the R/V Al Amir Moulay Abdallah of the National Institute of Fisheries Research (INRH).

Morphometrics

For each shark, total length (TL) with caudal fin in natural position, fork length (FL), standard precaudal length (PCL), distance between the tip of the snout and the origin of the first dorsal (D1L), and distance between the end of the snout and the origin of the pelvic fin (PvL) were measured over the curve of the body to the nearest centimetre (Ebert

& Stehmann, 2013). Body weight was measured to the nearest kg using an electronic scale. The sharks are not gutted at sea, so the body was whole when measured. The data were expressed as means ± standard deviations (mean ± SD).

The relationships between the different measurements were determined using a linear regression model (Alam *et al.*, 2013):

$$Y = a + b * X$$

where *Y* and *X* are different body lengths (cm), *a* is the proportionality constant, and *b* is the coefficient of regression.

Following Le Cren (1951) and Ricker (1975), the relationship between the TL and weight was estimated as follows:

$$W(t) = a * L^{\ b}$$

where *W* is the body weight (kg), *TL* is the total length (cm), *a* is the intercept, and *b* is the slope of the relationship. When applying this formula to sampled fish, *b* may deviate from the "ideal value" of 3, which represents isometric growth, because of certain environmental circumstances or the condition of the fish themselves (Froese, 2006). When *b* is less than 3, it means that fish become slimmer with increasing length, and growth will be negatively allometric (minor). When *b* is greater than 3, it means that the fish become heavier, showing positive allometric (major) growth and reflecting optimum conditions for growth (Froese, 2006).

Von Bertalanffy growth parameters

Growth in length has been described using the von Bertalanffy (1938) growth equation based on either observed or back-calculated length at ages. The length frequency distribution analysis (LFDA) software sub-programme of the electronic length frequency analysis (ELEFAN) package is also a PC-based computer package for estimating growth parameters from fish length frequency distributions by the von Bertalanffy growth curve (Kirkwood *et al.*, 2003). The ELEFAN procedure first restructures length frequencies and then fits a VBG curve to the restructured data. The standard von Bertalanffy growth function (VBGF) is as follows:

$$L(t) = L_\infty * (1 - e\ (^{-k * (t - t_0)}))$$

where, *Lt* is length at age t, L_∞ is the asymptotic length to which the fish grows, *k* is the growth-rate parameter, and t_0 is the nominal age at which the length is zero.

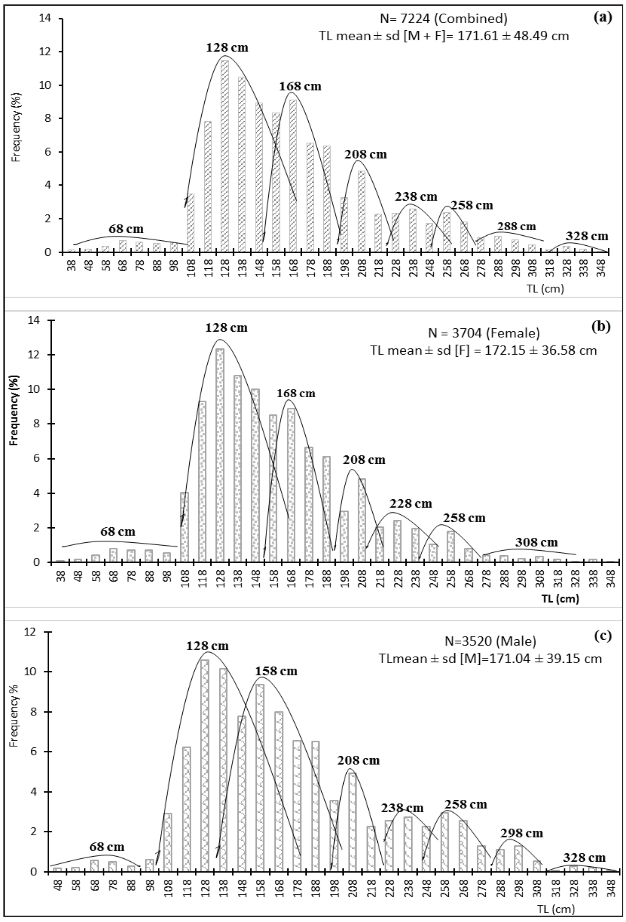


Fig. 2: Length frequency distributions for blue sharks caught off the Central Atlantic coast of Morocco during the Oct 2017–Oct 2019 period: (a) both sexes combined, (b) females, and (c) males.
Sl. 2: Velikostna porazdelitev sinjih morskih psov, ujetih ob obali srednjega Atlantika v Maroku v obdobju od oktobra 2017 do oktobra 2019, na podlagi dolžine: (a) oba spola skupaj, (b) samice in (c) samci.

Growth performance comparisons were made using the growth performance index (Φ'), which is preferred to the use of *L*∞ and *K* individually (Pauly & Munro, 1984) and is computed as:

$$\Phi' = \log\ (\mathrm{K}) + 2\ log\ (L_\infty).$$

Longevity

Theoretical longevity (t_{max}) was estimated following Taylor (1958) and Fabens (1965). The respective equations for longevity based on the parameters of the VBGF following Taylor (1958) and Fabens (1965) are as follows:

$$t_{max} = t_0 + 2.966/k \quad \text{and} \quad t_{max} = 5\ (\ln 2)/\mathrm{k}$$

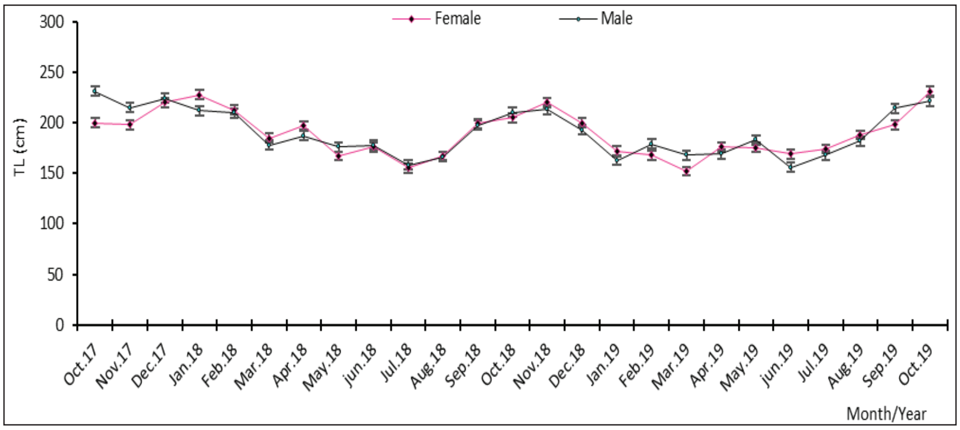


Fig. 3: Monthly median sizes of blue sharks landed at the port of Sidi Ifni during the October 2017–October 2019 period.
Sl. 3: Mesečne srednje velikosti sinjih morskih psov, ki so jih iztovorili v pristanišču Sidi Ifni v obdobju od oktobra 2017 do oktobra 2019.

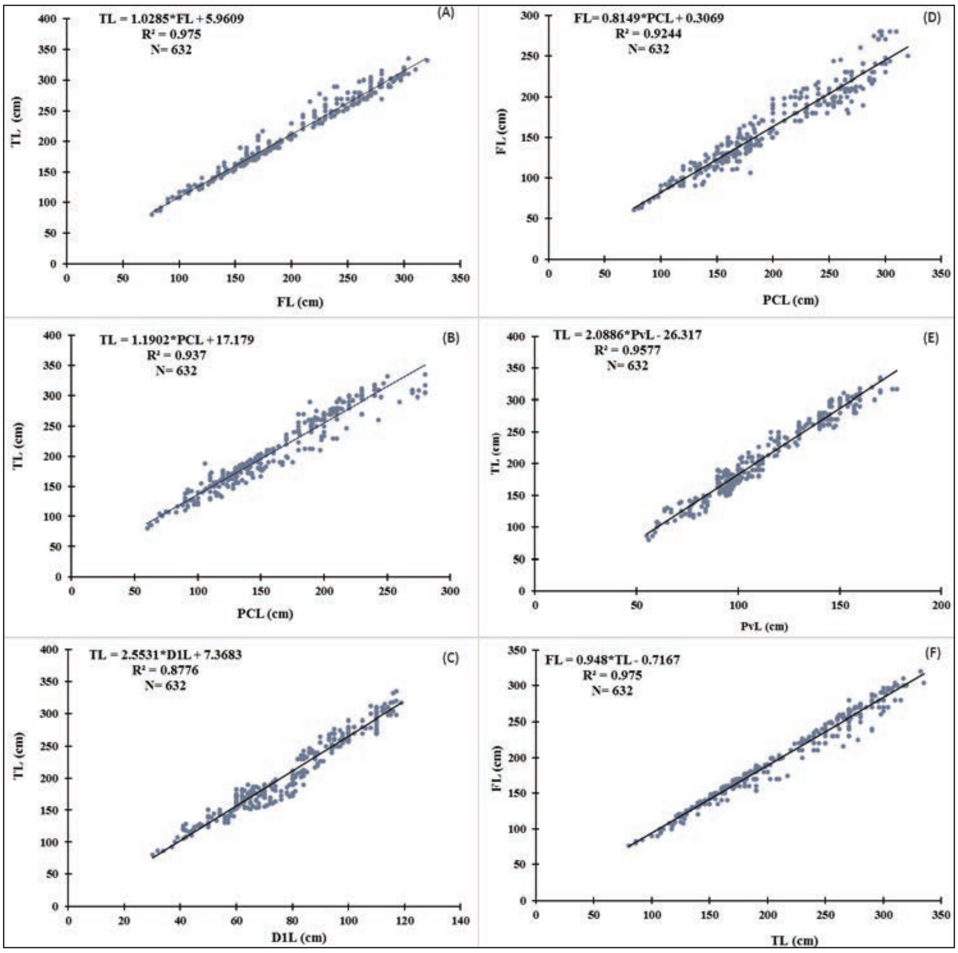


Fig. 4: Relationships between different length measurements of blue sharks landed at the port of Sidi Ifni during the period from October 2017 to October 2019.
Sl. 4: Odnosi med različnimi meritvami dolžine sinjih morskih psov, ki so jih iztovorili v pristanišču Sidi Ifni v obdobju od oktobra 2017 do oktobra 2019.

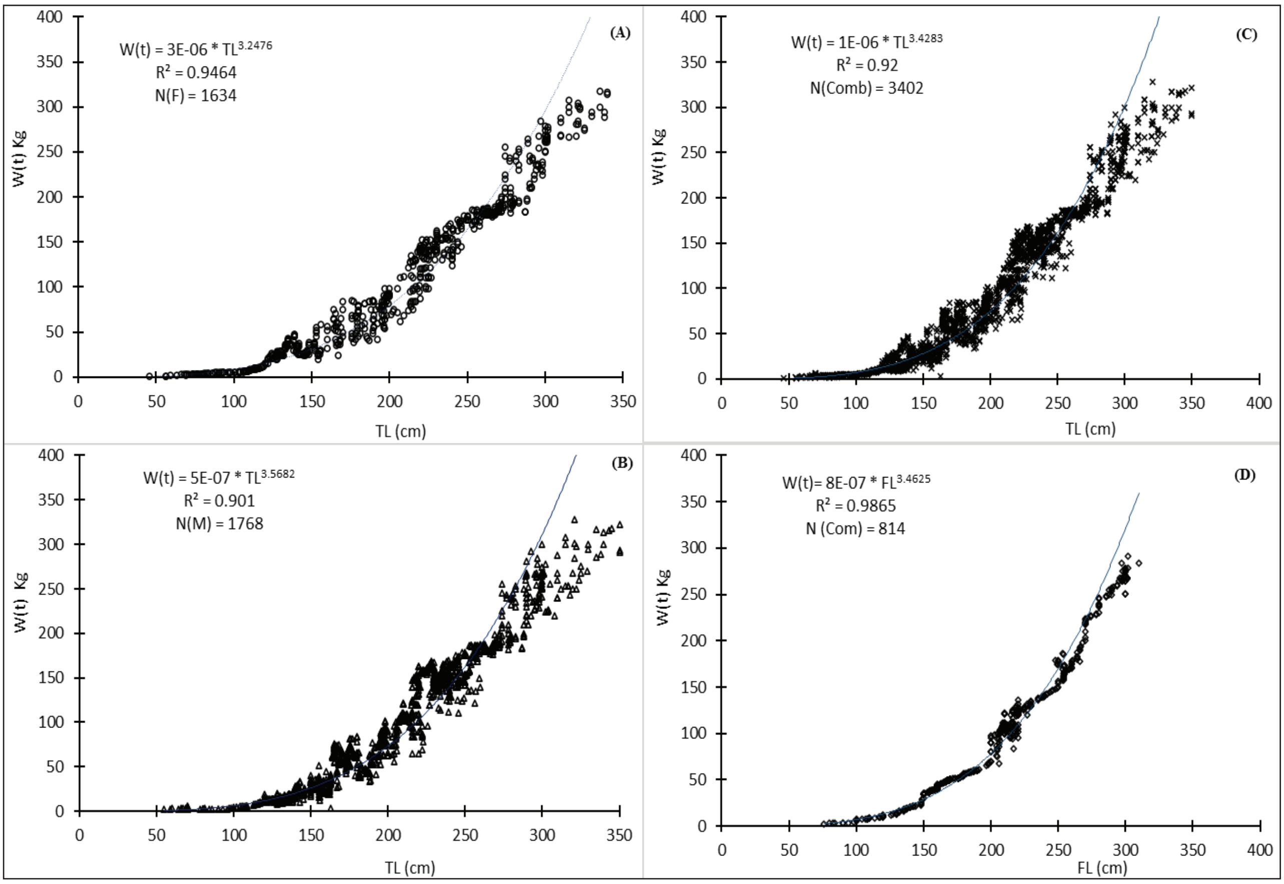


Fig. 5: LWR for blue sharks caught off the Moroccan Central Atlantic coast, for females (F), males (M), and the two sexes combined (Comb).
Sl. 5: LWR za sinje morske pse, ujete ob maroški centralni atlantski obali, za samice (F), samce (M) in oba spola skupaj (kombinirano).

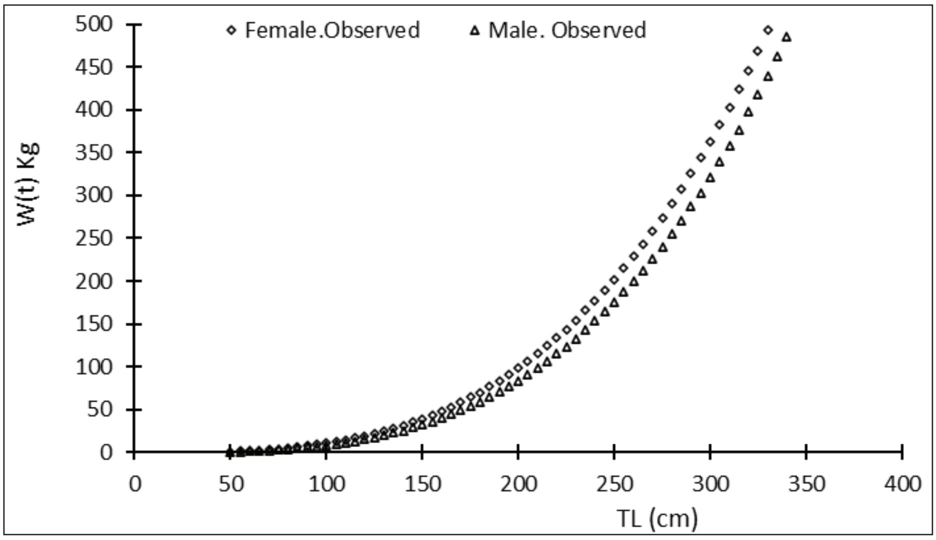


Fig. 6: LWR of** P. glauca **caught off the Central Atlantic coast of Morocco.
Sl. 6: LWR za primerke vrste** P. glauca**, ujete ob obali srednjega Atlantika v Maroku.

Tab. 1: Von Bertalanffy growth equation parameters of the blue shark.
Tab. 1: Parametri von Bertalanffyjeve rastne krivulje za sinjega morskega psa.

Sex	N	L_∞ (cm)	k (*Year*$^{-1}$)	t_0	Φ'	t_{max} (Longevity)
Combined	7224	413.59	0.20	-0.76	4.53	14 - 17
Female	3704	398.58	0.18	- 0.01	4.45	16.4 - 19.2
Male	3520	435.72	0.17	- 0.23	4.50	17 - 20

Tab. 2: The size distribution of** P. glauca **in various regions of the world.
Tab. 2: Velikostna porazdelitev primerkov vrste** P. glauca **v različnih predelih sveta.

Zone	Size (TL) cm	Size (FL) cm	Reference
Indian ocean	154 - 396	130 - 330	Gubanov *et al.*, 1975
North-east Atlantic	64 - 218	55 - 183	Henderson *et al.,* 2001
North-western Atlantic ocean	35 - 514	31 - 429	Kohler *et al.*, 2002
South-west in the north Atlantic ocean	53 - 366	46 - 306	Kohler *et al.*, 2002
North-eastern Atlantic ocean	37 - 305	32 - 255	Kohler *et al.*, 2002
South-east coast of the north Atlantic ocean	70 - 349	60 - 292	Kohler *et al.*, 2002
South West England ocean	80 - 219	68 - 184	Kohler *et al.*, 2002
Portugal waters of Atlantic	40 - 159	35 - 134	Kohler *et al.*, 2002
South-eastern Pacific ocean	56 - 310	___	Bustamante & Bennett, 2013
Moroccan waters	50 - 340	___	Hamdi *et al.,* 2018
Present study	48 - 350	36 - 330	

RESULTS

Length frequency distribution

A total of 7224 blue sharks were examined, of which 3704 females (48–340 cm TL) and 3520 males (55–350 cm TL). The females were generally more numerous than males in all small and medium length classes [48–198 cm]. Contrarily, the males were more numerous than females in the remaining large length classes [200–350 cm] (Figs. 2 b, c). The length–frequency modes for each sex and sexes combined showed eight distinct modes: 68 cm – 128 cm – 168 cm – 208 cm – 238 cm – 258 cm – 288 cm – 328 cm (Figs. 2 a, b & c).

The monthly median sizes are shown in Fig. 3. The most common sizes varied between 130 and 225 cm (TL). Greater sizes (> 200 cm TL) were observed during autumn and in the beginning of winter (September, October, November, December, and January) in both sexes. The largest observed size of 350 cm (TL) was recorded in October 2018. Smaller blue sharks (< 200 cm TL) are present during the winter, spring, and summer seasons.

Total length–fork length relationships

Morphometric studies are essential to determine the growth form and growth rate of a species, which is very important for a proper exploitation of a species' population. With reference to Figure 5, of the 7224 blue sharks, only the lengths of 632 sharks were compared. Relationships between TL & FL and other body measurements of *P. glauca* showed good linear regression with R^2 values ranging from 0.8776 to 0.975 (Fig. 4).

Length-weight relationship

The allometric equations between the two variables *W (t)* and *L (t)* showed a significantly major

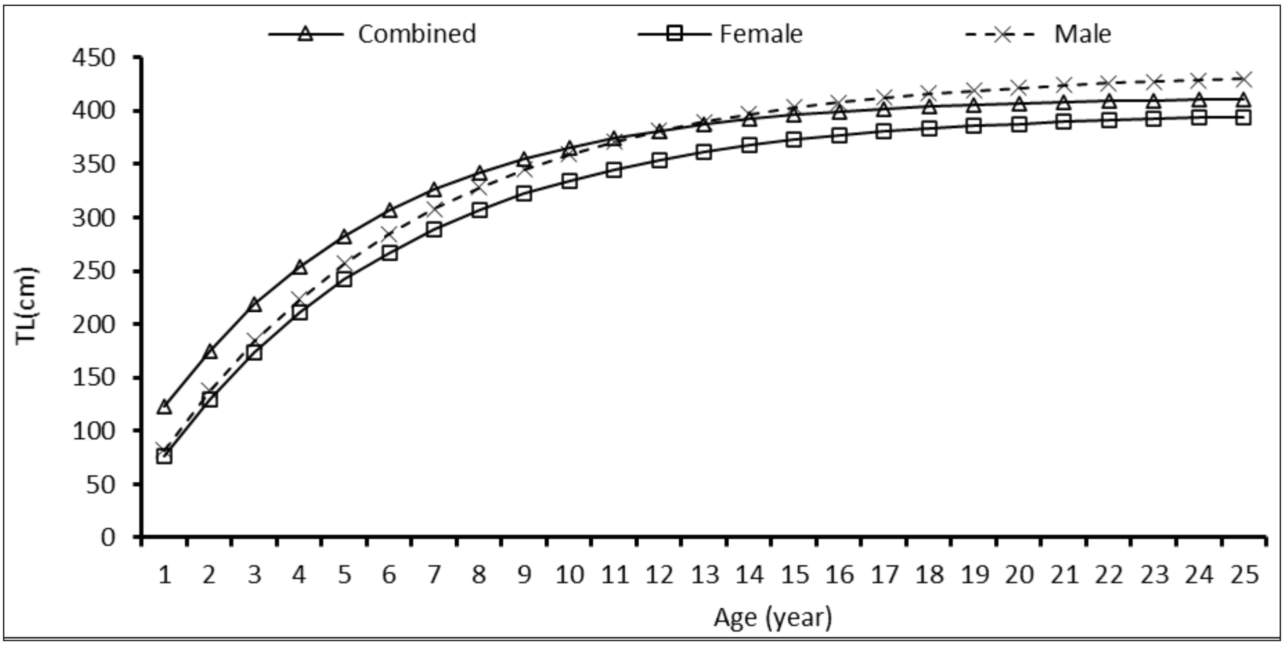


Fig. 7: The von Bertalanffy growth curves of blue sharks caught off the Central Atlantic coast of Morocco.
Sl. 7: Von Bertalanffyjeva rastna krivulja sinjih morskih psov, ujetih ob obali srednjega Atlantika v Maroku.

allometry (weight increasing faster than length) for males, females, and both sexes combined. The blue shark LWR parameters for males, females, and both sexes combined are shown in Fig. 5.

Figure 6 shows that the LWR for both sexes are similar. A comparison of the length-weight relationship in both sexes using the chi-square test contingency tables with 61 size classes (n = 61, ddl = 60) shows no significant difference between the LWR of both sexes ($X^2 = 2.5815 < 79.0819$ at ddl = 60 and p = 0.05) (Fig. 6).

Von Bertalanffy growth parameters

The growth performance indices (Φ’) for both sexes were similar. The longevity estimates, following the methods of Taylor (1958) and Fabens (1965), were 14 and 17 years, respectively for the two sexes combined, 16.4 and 19.2 years, respectively, for females, and 17 and 20 years, respectively, for males (Tab. 1).

The representation of the von Bertalanffy growth equation curves for females and males of the blue shark shows that the males grow faster than females from the age of about 2 years onward, and are larger than females at any age thereafter (Fig. 7).

DISCUSSION

The size distribution of the blue sharks examined in the present study showed that the total exploited population was divided into eight modes. Hamdi *et al.*, (2018), who examined 505 blue sharks caught during between 2015 and 2017, sampled once a week at the fish market in Casablanca, Morocco, established more than 4 modes in their study, with the measured sizes between 50 cm and 340 cm TL. Males and females had average TL sizes of 184.37 cm and 164.71 cm, respectively. The most dominant sizes were between 120 and 150 cm TL. Large individuals predominated in June and December. The difference between Hamdi’s study and the present one is that our samples were received from the landings of blue sharks at different ports in Morocco. Moreover, the size distribution of blue shark has been studied independently in several areas around the world and shows spatiotemporal variation (Tab. 2).

Several types of length measurement have been used by various researchers in describing shark morphometrics. Most commonly, these include total length (TL), fork length (FL), and precaudal length (PCL). There are several conversions that can be made between length types that have been developed and published. For the Atlantic Ocean and the Pacific North of the Japanese Ocean, Hazin *et al*. (1991) and McKinnell *et al*. (1998), respectively, reported relationships among TL, FL, and PCL. Kohler *et al*. (1996), Campana *et al*. (2005), Poisson (2007), and Castro *et al*. (1995) calculated the regression between TL and FL. Our study used all of these measurements, in addition to the distance between the tip of the snout and

Tab. 3: Relationships between different body sizes of** P. glauca **from regions around the world.
Tab. 3: Odnosi med različnimi telesnimi velikostmi pri vrsti** P. glauca **iz različnih predelov sveta.

Region/ Author	N	Relational parameters	Size range (cm)	Regression equation	R^2
North central pacific (Nakano *et al.*, 1985)	_	PCL / TL	_	PCL = - 0.2505 + 0.762* TL	_
Atlantic Ecuadorian Southwest (Hazin *et al.*, 1991)	73	FL / TL	_	FL = 11.27 + 0.78* TL	0.94
		PCL / TL	_	PCL = 3.92 + 0.74* TL	0.95
Gulf of Guinea (Castro & Mejuto, 1995)	62	FL / TL	[117- 330]	FL = 1.061 + 0.8203* TL	0.9987
		TL / FL	[94- 273]	TL = 1.716 + 1.2158* FL	0.9987
Northwest Atlantic (Kholer *et al.*, 1996)	572	FL / TL	_	FL = 1.308 + 0.831* TL	0.9966
Pacific North of the Japanese Ocean (Mckinnell *et al.*, 1998)	187	PCL / TL		PCL = -1.95 + 0.76* TL	_
		TL / PCL	_	TL = 2.55 + 1.31* PCL	_
	242	TL / FL	_	TL = 3.62 + 1.35* FL	_
		FL / TL	_	FL = 2.68-0.70* TL	_
	190	FL / PCL	_	FL = 0.53 + 1.03* PCL	_
		PCL / FL	_	PCL = - 0.51 + 0.97 FL	_
Atlantic Canadian (Campana *et al.*, 2005)	792	FL / TL	_	FL= - 1.2 + 0.842* TL	_
		TL / FL	_	TL = 3.8 + 1.17* FL	_
Indian Ocean (Poisson, 2007)	_	TL / FL	[130 - 330]	TL = 41.03 + 1.175* FL	_
Present study	632	TL / FL	[76 - 335]	TL = 5.9609 + 1.0285* FL	0.975
		TL / PCL	[60 - 335]	TL = 17.179 + 1.1902* PCL	0.937
		TL / D1L	[30 - 335]	TL = 7.368 + 2.5531* D1L	0.8776
		FL / PCL	[60 - 320]	FL = 15.079 + 1.1304* PCL	0.9244
		TL / PvL	[55 - 335]	TL = - 26.317 + 2.0886* PvL	0.9577
		FL / TL	[76 - 335]	FL = - 0.7167 + 0.948* TL	0.975

the origin of the first dorsal (D1L), and the distance between the end of the snout and the origin of the pelvic fin (PvL). Thus, we found linear regressions between the various body measurements which are in line with findings from other regions (Nakano *et al.*, 1985; Hazin *et al.*, 1991; Castro & Mejuto, 1995; Kholer *et al.*, 1996; Mckinnell *et al.*, 1998; Campana *et al.*, 2005; Poisson, 2007) (Table 3). There are three length measurements (i.e., total length, fork length, and precaudal length) used as standard length in sharks (Francis, 2006). Precaudal length has only been used by Nakano & Seki (2003). It is recommended to use one of these three length measurements as a standard for measuring the length of a shark to reduce the differences in the measured length of the shark.

The LWRs computed in the present study coincided with the equations computed for the populations of *Prionace glauca* occurring in the Pacific and Atlantic Oceans. Size increased proportionally but less rapidly than weight, and both sexes had similar weights at same lengths. This is contrary to the studies of Hamdi *et al.*, (2018) in Moroccan water and of Harvey (1989) in the Bay of Monterey, California, which indicated isometric growth. While Hazin (1986) recorded a minor allometry in the Atlantic Ocean for females, the same result was recorded by Draganik & Pelczarski

Tab. 4: Parameters of the LWR (length–weight relationship) for the two sexes of the blue shark** P. glauca **combined from different study areas.

Tab. 4: Parametri LWR (razmerje med dolžino in maso) za oba spola sinjega morskega psa** (P. glauca)**, združeni iz različnih raziskanih območij.

Region /Authors	Sex	N	Length (cm)	*W(t) = a * L^b^*	R²	Allometry
Central Pacific (Strasburg, 1958)	Comb	-	TL	$W(t) = 4.018 * 10^{-6} TL^{3.134}$	-	Major
Atlantic Ocean (Stevens, 1975)	M	17	TL	$W(t) = 0.392 * 10^{-6} TL^{3.41}$	0.999	Major
	F	450	TL	$W(t) = 0.131 * 10^{-5} TL^{3.20}$	0.999	
Gulf of Guinea (Castro, 1983)	Comb	4529	TL	$W(t) = 3.18 * 10^{-6} TL^{3.1313}$	0.976	Major
Atlantic North (Draganik Pelczarski, 1984)	M	260	TL	$W(t) = 9.94 * 10^{-4} TL^{2.0005}$	-	Minor
	F	31	TL	$W(t) = 7.95 * 10^{-4} TL^{2.0473}$	-	
North Pacific Center (Nakano *et al.*, 1985)	M	285	TL	$W(t) = 3.838 * 10^{-6} TL^{3.174}$	0.997	Major
	F	148	PCL	$W(t) = 2.328 * 10^{-6} PCL^{3.294}$	0.994	
Atlantic Ocean (Hazin, 1986)	M	37	FL	$W(t) = 1.377 * 10^{-7} FL^{3.672}$	0.95	Major
	F	60	FL	$W(t) = 5.677 * 10^{-6} FL^{2.928}$	0.83	Minor
Monterey Bay, California (Harvey, 1989)	Comb	150	TL	$W(t) = 2.57 * 10^{-5} TL^{3.05}$	0.849	Isometric
Pacific North (Nakano 1994)	M	2910	PCL	$W(t) = 3.293 * 10^{-6} PCL^{3.225}$	0.993	Major
	F	2890	PCL	$W(t) = 5.388 * 10^{-6} PCL^{3.102}$	0.992	
Atlantic Northwest (Kohler *et al.*, 1996)	Comb	4529	FL; [52 - 288]	$W(t) = 3.84 * 10^{-6} FL^{3.1313}$	-	Major
Atlantic Northest (Garcia-cortés & Mejuto, 2002)	Comb	354	FL; [75 - 250]	$W(t) = 8.04 * 10^{-6} FL^{3.232}$	-	Major
East tropical Atlantic (Garcia-Cortés & Mejuto, 2002)	Comb	743	FL; [120 - 260]	$W(t) = 0.638 * 10^{-6} FL^{3.278}$	-	Major
Central tropical Atlantic (Garcia-cortés & Mejuto, 2002)	Comb	164	FL; [140 - 245]	$W(t) = 0.956 * 10^{-6} FL^{3.209}$	-	Major
Southwest Atlantic (Garcia-cortés & Mejuto, 2002)	Comb	166	FL; [135 - 250]	$W(t) = 1.57 * 10^{-6} FL^{3.104}$	-	Major
Pacifique North (Joung, Hsu, Liu & Wu, 2011)	Comb	-	FL	$W(t) = 3 * 10^{-6} FL^{3.23}$	-	Major
Northeast Atlantic (Biton *et al.*, 2015)	Comb	102	TL	$W(t) = 2 * 10^{-6} TL^{3.1625}$	0.9575	Major
Moroccan waters (Hamdi *et al.*, 2018)	Comb	130	TL	$W(t) = 3 * 10^{-6} TL^{3.0389}$	0.9836	Isometric
	M	-	TL	$W(t) = 3 * 10^{-6} TL^{3.0504}$	0.9849	
	F	-	TL	$W(t) = 4 * 10^{-6} TL^{3.0123}$	0.9819	
Present Study	Comb	3402	TL; [48 - 350]	$W(t) = 10^{-6} TL^{3.4283}$	0.92	Major
		814	FL; [76 - 320]	$W(t) = 8 * 10^{-7} FL^{3.4625}$	0.9865	
	M	1768	TL; [55 - 340]	$W(t) = 5 * 10^{-7} TL^{3.5682}$	0.901	
	F	1634	TL; [48 - 350]	$W(t) = 3 * 10^{-6} TL^{3.2476}$	0.9464	

Tab. 5: Von Bertalanffy parameters (k, L_∞, and t_0) obtained by various authors for the blue sharks, for the sexes combined and separately.
Tab. 5: Von Bertalanffyjevi parametri (k, L_∞ in t_0), ki so jih dobili različni avtorji za sinje morske pse, za spola skupaj in ločeno.

Region / Authors	Sex	Length	L_∞ (cm)	(*) L_∞ Conversion to TL_∞ (cm)	k (Year⁻¹)	t_0 (Year)	t_{max} (Year) Longevity	Methods
Atlantic North (Aasen, 1966)	Comb	TL	394	394	0.133	-0.802	21.5 - 26	-
North East Atlantic (Stevens, 1975)	Comb	FL	309	423	0.110	-1.035	26 - 31.5	vertebrae
Northeast Pacific California (Cailliet *et al.*, 1983)	Comb F M	TL	265.5 295.3 241.9	265.5 295.3 241.9	0.223 0.251 0.175	-0.80 -1.11 -0.80	12 - 15.5 10 - 13 16 - 19.8	vertebrae
Pacific Northwest (Tanaka, 1984) **cited by** (Nakano & Seki, 2003)	F M	PCL	256.1 308.2	338.9 408	0.116 0.094	-1.37	30 - 36.8	vertebrae
North Pacific (Nakano, 1994) **cited by** (Semba & Yokoi, 2016)	F M	PCL	243.3 289.7	321.9 383.5	0.144 0.12	-0.85 -0.759	19 - 24 23 - 28.8	vertebrae
North East Atlantic (Silva *et al.*, 1996)	Comb F M	FL	284 382 309	339.96 457.87 370	0.14 0.09 0.12	-1.08 -1.19 -1.05	20 - 24.7 31.7 - 38 23.6 - 28.8	vertebrae
Atlantic (Henderson *et al.*, 2001)	Comb	TL	376.5	376.5	0.120	-1.330	23 - 28.8	vertebrae
North Atlantic (Skomal & Natanson, 2003)	Comb F M	FL	286.8	341.16 343.8 337.9	0.17 0.130 0.180	-1.43 -1.77 -1.316	16 - 20.4 21 - 26.6 15 - 19.3	vertebrae and tags
Atlantic southwest (Hazin & Lessa, 2005)	Comb	TL	352	352	0.16	-1.01	17.5 - 21	vertebrae
Pacific (Manning & Francis, 2005)	F M	FL	342.9 267.5	320.11 410.81	0.126 0.088	-1.047 -1.257	22.5 - 27.5 32.4 - 39	-
Pacific Northwest Mexico (Blanco-Parra *et al.*, 2008)	Comb F M	TL	303.4 237.5 299.8	303.4 237.5 299.8	0.10 0.15 0.10	-2.68 -2.15 -2.44	27 - 34.6 17 - 23 27.2 - 34	vertebrae
Mediterranean (Megalofonou *et al.*, 2009)	Comb	TL	401.5	401.5	0.13	-0.62	22.2 - 26.6	vertebrae
Pacific North (Hsu *et al.*, 2011)**, cited by** (Semba & Yokoi, 2016)	F M	TL	317.4 375.8	317.4 375.8	0.172 0.121	-1.123 -1.554	16 - 20.4 23 - 28.6	-
South Africa (Jolly *et al.*, 2013)	Comb F M	TL	311.6 334.7 294.6	311.6 334.7 294.6	0.12 0.11 0.14	-1.66 -2.19 -1.30	23 - 28.8 24.7 - 31.5 19.8 - 24.7	vertebrae
Pacific North (Fujinami *et al.*, 2016)**, Cited by** (Semba & Yokoi, 2016)	F M	PCL	256.3 284.8	339.2 377	0.147 0.117	-0.97 -1.34	19.2 - 23.5 24 - 29.6	-
Moroccan Waters (Hamdi *et al.*, 2018)	Comb	TL	392.5	392.5	0.21	-0.402	13.4 - 16.5	size distribution

central South Pacific Ocean (Joung *et al.*, 2018)	F M	TL	330.4 376.6	330.4 376.6	0.164 0.128	-1.29 -1.48	16.8 - 21 21.6 - 27	vertebrae
Southern of Nusa Tenggara Indonesia (Chodrijah *et al.*, 2021)	F M	TL	400 390.5	400 390.5	0.28 0.25	-0.2921 -0.3307	10 - 13 11.5 - 14	size distribution
Present study	Comb F M	TL	413.59 398.58 435.72	413.59 398.58 435.72	0.20 0.18 0.17	-0.76 -0.01 -0.23	15 - 17.5 16.5 - 19 17 - 20	size distribution

(*): PRC = 0.76 * TL – 1.95 (Mc Kinnell & Seki, 1998). FL = 1.3908 + 0.8313 * TL (Kohler et al. 1996).

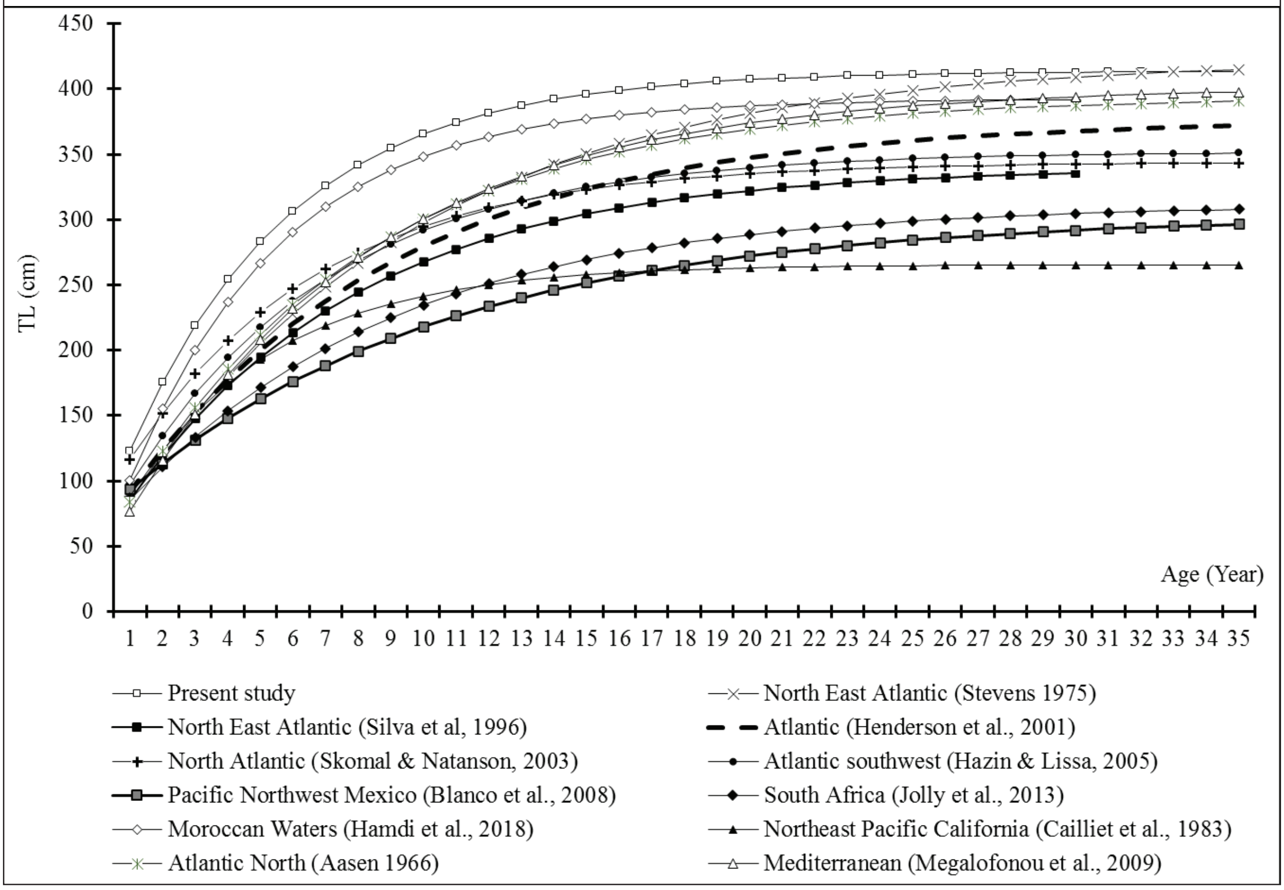


Fig. 8: Comparison of the von Bertalanffy growth curves for the sexes combined in different regions.
Sl. 8: Primerjava von Bertalanffyjevih krivulj rasti za oba spola iz različnih predelov.

(1984) in the North Atlantic for both sexes. This difference may be due to samples being taken from different places, at different times, and in different meteorological conditions, as well as to weighing on board, which may have led to errors during the weighing process. The comparison of the different equations is shown in Table 4.

The use of LFDA software (ELEFAN sub-program) allowed us to estimate the growth parameters of the targeted species in Central Atlantic Ocean waters off the Moroccan coast. Length frequencies (LFDA software with ELEFAN subprogram) were used to calculate the von Bertalanffy parameters. Our *k* value was 0.20/year. Branstetter (1987) categorized *k* values as follows: when a species grows slowly, the measured weight is $0.05 \leq k \leq 0.10$ $year^{-1}$, intermediate growth is recorded when the weight is $0.10 \leq k \leq 0.20$ $year^{-1}$, and rapid growth is recorded when the weight is $0.2 \leq k \leq 0.50$ $year^{-1}$. Our study has shown intermediate growth for

this species in this region (Central Atlantic coast of Morocco), which is in agreement with Nakano, 1994; Henderson *et al*., 2001; Skomal & Natanson, 2003; Hazin & Lessa, 2005; Hsu *et al*., 2011; Jolly *et al*., 2013; Fujinami *et al*., 2016. However, other studies, such as Hamdi *et al*., (2018), Cailliet & Bedford (1983) and Chodrijah & Faizah (2021) reported large *k* values. In addition, studies from the Pacific reported a much higher maximum observed age (over 30 years) for both sexes compared to the estimates in the present study (between 15 and 20 years). These results suggest that the blue sharks in the Moroccan Central Atlantic have a shorter maximum life expectancy than those in some areas in the Pacific, Mediterranean, and North Atlantic. However, since the results of our study related to growth and longevity are consistent with those of several studies of water conducted in Morocco, Indonesia, California, the North Atlantic, and the Atlantic Southwest (Tab. 5), the differences observed in the lengths and weights of sharks may be due to the water temperature, since the latter has been found to importantly affect the growth rate (Simpfendorfer *et al.,* 2002).

Our study showed a different growth rate between the sexes, similarly to studies from the Pacific (Tanaka et al., 1984; Nakano et al., 1994; Manning & Francis, 2005; Blanco-Parra et al., 2008; Hsu et al., 2011; Fujinami et al., 2016), where males were larger than females. In studies from South Africa (Jolly *et al*., 2013), the North Atlantic (Skomal & Natanson 2003), the Northeast Atlantic (Silva *et al*., 1996), and the Pacific Northeast California (Cailliet & Bedford, 1983) females were larger than males (Tab. 5). These regional differences may be due to migratory patterns, distribution, and movements of the blue shark, which are strongly influenced by seasonal variations, water temperature, reproductive conditions, and prey availability (Kohler *et al*., 2002). t_0 values are also extremely low for females; t_0 = - 0.01 years is supposed to be an indication of gestation, including growth retardation, based on the assumption that intrauterine growth is the same as postpartum (Fujinami & Semba, 2016). Figure 8 shows that, generally, the growth rate of blue shark is rapid in the first years, slowing down during ages 10–15, and remaining constant beyond this age. Our study's growth curve is the highest and fastest ever recorded, conceivably due to the presence of a large number of newborns in this area and their absence in other study areas, which influenced our results (Fig. 8). Blue sharks grow faster than most other shark species in the family Carcharhinidae (Branstetter & Stiles, 1987; Casey & Natanson, 1992), which makes them possibly the fastest growing shark species in general (Nakano & Stevens, 2008). The differences in sample sizes of each area precludes the conclusion that blue sharks in different regions have different growth characteristics. Also, other studies based on determining the age by counting vertebral rings have yielded different results than those using size frequencies.

CONCLUSIONS

This study provides biological parameters related to morphometrics and growth of the blue shark, *Prionace glauca,* in the Central Atlantic Coast of Morocco. Total lengths showed a multimodal distribution with a length range of 48–350 cm, where large individuals were observed in autumn and winter (September, October, November, December, and January). The morphometric study of the blue shark showed that the lengths measured between different points on the body of the specimens were proportional and in perfect positive correlation to total length (TL). Furthermore, the LWR study, in both sexes, showed a major growth allometry. In the Central Atlantic waters off the Moroccan coast, the blue shark seems to be growing faster than in other study areas. These findings could be applied to regional management of blue shark fishery. Additional studies on the reproductive cycles of females and local pupping areas are needed to protect neonates. Although Hamdi *et al*. (2018) have already shown that Morocco is a shark birthing site and nursery area, it is highly recommended that these be more accurately identified and protected to prevent the capture of young individuals.

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DOLŽINSKO-MASNI ODNOS IN OCENA RASTI PRI SINJEM MORSKEM PSU (*PRIONACE GLAUCA*) IZ OSREDNJE ATLANTSKE OBALE MAROKA

Jihade ALAHYENE & Brahim CHIAHOU
Chouaib Doukkali University, Faculty of Sciences, Department of Biology, El Jadida, Morocco
e-mail: jihad.20081@hotmail.com

Hammou EL HABOUZ & Abdelbasset BEN-BANI
National Fisheries Research Institute (INRH), Agadir, Morocco

POVZETEK

*Sinji morski pes (*Prionace glauca*) je široko razprostranjen v Atlantskem oceanu in v Sredozemskem morju. Avtorji predlagajo za to vrsto načrt upravljanja, ki temelji na bioloških podatkih, vključno z dolžinsko-masnim odnosom in drugimi rastnimi parametri, morfometričnimi podatki in podatki o dolgoživosti. Sinjega morskega psa so redno vzorčili v obdobju 24 mesecev (oktober 2017 – oktober 2019). Primerke so lovili ribiči ob srednje atlantski obali Maroka, še posebej v regiji Sidi Ifni s tradicionalnimi plovili, in v sezonskih akustičnih raziskavah. Pregledali so skupno 7224 primerkov, med katerimi je bilo 3704 samic in 3520 samcev. Celotna dolžina pri samicah je bila od 48 cm do 340 cm in od 55 cm do 350 cm pri samcih. Oba spola sta imela dolžinsko-masni odnos* $W(t) = 10^{-6} * TL^{3,4283}$*, kar kaže na značilno veliko alometrijo. Parametri von Bertalanffyjeve enačbe za oba spola skupaj so bili* $L\infty = 413,59$ *cm,* $k = 0,20$ *leto*$^{-1}$ *in* $t_0 = 0,76$*. Dolgoživost (tmax) je bila višja od 17 let pri obeh spolih.*

Ključne besede: *Prionace glauca*, morfometrija, dolžina-masa, Von Bertalanffyjevi parametri, dolgoživost

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OCCURRENCE OF *CUBICEPS GRACILIS* (NOMEIDAE) IN THE EASTERN MEDITERRANEAN SEA

Okan AKYOL & Altan LÖK
Ege University Faculty of Fisheries, 35440 Urla, İzmir, Türkiye
e-mail: okan.akyol@ege.edu.tr

Funda ERDEM
Directorate of Agriculture and Forestry, Döşemealtı, Antalya, Türkiye

ABSTRACT

This paper reports an additional record of Cubiceps gracilis *(Lowe, 1843) indicating the extension of the species' distribution into the eastern Mediterranean Sea. On 7 January 2022, a single specimen of* C. gracilis *was caught by bottom trawl at a depth of about 400 m off Antalya in the southern coasts of Turkey. This oceanic fish is still very rare in the eastern Mediterranean Sea. This is the fourth record of* C. gracilis *in the eastern Mediterranean Basin, the first after 2006.*

Key words: Driftfish, additional record, measurements, Antalya

PRESENZA DI *CUBICEPS GRACILIS* (NOMEIDAE) NEL MEDITERRANEO ORIENTALE

SINTESI

L'articolo riporta un nuovo ritrovamento di Cubiceps gracilis *(Lowe, 1843), che indica l'estensione della distribuzione della specie nel Mediterraneo orientale. Il 7 gennaio 2022, un singolo esemplare di* C. gracilis *è stato catturato con una rete a strascico ad una profondità di circa 400 m, al largo di Antalya lungo le coste meridionali della Turchia. Questo pesce oceanico è ancora molto raro nel Mediterraneo orientale. Si tratta del quarto ritrovamento di* C. gracilis *nel bacino del Mediterraneo orientale, il primo dopo il 2006.*

Parole chiave: Centrolofo alalunga, nuovo ritrovamento, misurazioni, Antalya

INTRODUCTION

The driftfish (or longfin cigarfish), *Cubiceps gracilis* (Lowe, 1843) is an oceanic, epipelagic and mesopelagic fish species. Its young sometimes associate in groups with medusae, while adults generally occur singly (Haedrich, 1986).

C. gracilis commonly occurs both in Canada (northwest Atlantic) and the northeast Atlantic as far south as about 20°N off the African coast, including western Mediterranean (Froese & Pauly, 2021). It has recently expanded its distribution range throughout the Mediterranean, from Gibraltar to the Adriatic (Dulčić, 2002; Pešić *et al*., 2021), Antalya Bay (Golani *et al*., 2008), as well as the Bays of Sığacık and Fethiye in the Aegean Sea (Filiz *et al*., 2007; Irmak *et al*., 2007).

This paper presents a new and additional record of *C. gracilis* as a very rare species in the eastern Mediterranean Sea.



Fig. 1: *Cubiceps gracilis* ***caught off Antalya (ref. ESFM-PIS/2022-001, scale bar: 50 mm, photo: O. Akyol).***
Sl. 1: Klatež, Cubiceps gracilis, ujet v vodah pri Antalyji (ref. ESFM-PIS/2022-001, merilo 50 mm, foto: O. Akyol).

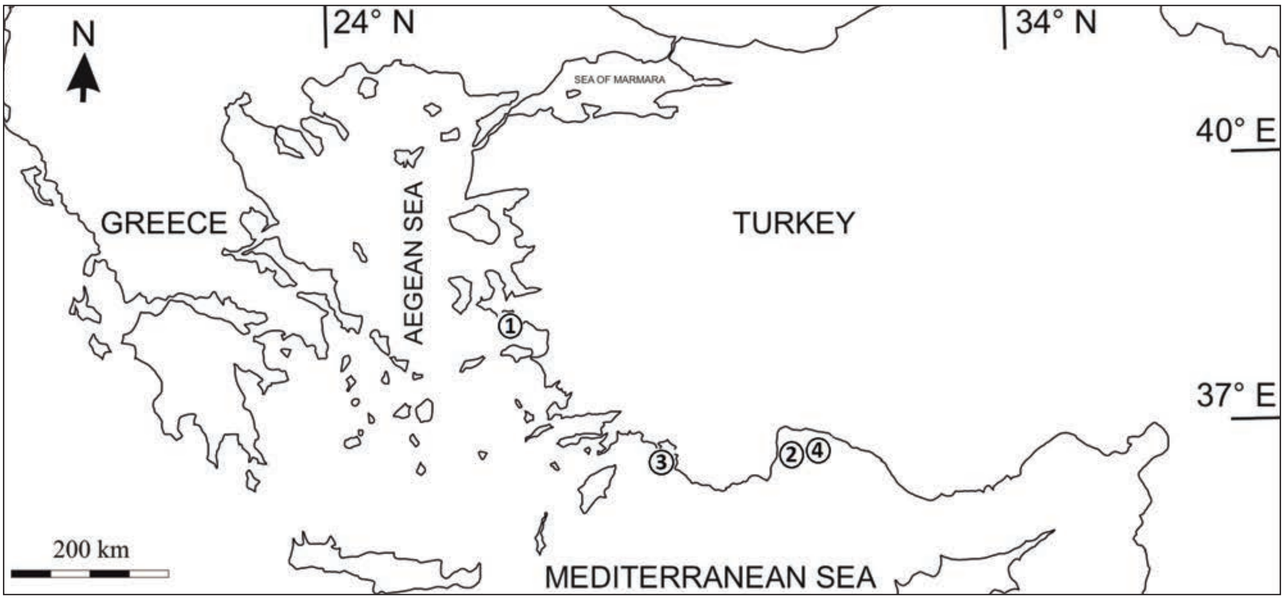


Fig. 2: Map showing records of *Cubiceps gracilis* ***in the eastern Mediterranean: (1) Sığacık Bay, Sept. 2005, (2) Gulf of Antalya, March 2006, (3) Fethiye Bay, July 2006, (4) Gulf of Antalya, Jan. 2022.***
Sl. 2: Zemljevid z označenimi zapisi o pojavljanju klateža v vzhodnem Sredozemskem morju: 1) zaliv Sığacık, September 2005, (2) zaliv Antalya, Marec 2006, (3) zaliv Fethiye, Julij 2006, (4) zaliv Antalya, Januar 2022.

Tab. 1: Morphometric measurements as percentages of total length (TL%) and meristic counts recorded in the *Cubiceps gracilis* ***captured off Antalya.***
Tab. 1: Morfometrične meritve, izražene kot delež celotne dolžine (%TL) in meristična štetja na primerku klateža, ujetega pri Antalyji.

Measurements	Size (mm)	Proportion (TL%)
Total length (TL)	190	
Fork length (FL)	169	88.9
Standard length (SL)	155	81.6
Pre-dorsal fin length	54	28.4
Pre-anal fin length	90	47.4
Pre-pectoral length	46	24.2
Head length	46	24.2
Eye diameter	12	6.3
Preorbital length	9	4.7
Meristic counts		
1st Dorsal fin rays	XI	
2nd Dorsal fin rays	I+22	
Anal fin rays	II+20	
Pectoral fin rays	20	
Ventral fin rays	I+5	
Weight (g)	61.2	

MATERIAL AND METHODS

On 7 January 2022, a single specimen of *Cubiceps gracilis* (Fig. 1) was captured by a bottom trawler at a depth of about 400 m in the Gulf of Antalya (Fig. 2) on the southern coasts of Turkey. The specimen was fixed in a 6% formaldehyde solution and deposited in the fish collection of Ege University, Fisheries Faculty (ESFM-PIS/2022-001).

RESULTS AND DISCUSSION

The specimen was measured to the nearest millimetre. It was 190 mm in TL and weighed 61.2 g. The morphometric measurements as percentages of total length (TL%) and the meristic counts recorded in *C. gracilis* are presented in Table 1. The specimen was identified via the combination of the following characters: two dorsal fins, the first with eleven spines, the second with one spine and 22 soft rays. Anal fin with two small spines, and soft ray portion with 20 rays. Long pectoral fin with 20 rays. Ventral fin with one spine and five rays. Scales on head extending forward almost to nostrils. Colour: brown and blackish. All measurements, counts, proportions, and colour patterns determined are in accordance with the descriptions of Haedrich (1986), Filiz *et al*. (2007), Golani *et al*. (2008), and Froese & Pauly (2021).

It is obvious that *Cubiceps gracilis* is gradually extending its range into the eastern basin of the Mediterranean. In fact, fishermen state that the species has been sporadically observed for a decade. The recent intermittent records of *C. gracilis* are shown in Table 2.

The maximum total length (TL) of *C. gracilis* is 107 cm, common TL length 18 cm (Froese & Pauly, 2021). Length at sexual maturity is 20 cm (Haedrich, 1986). The specimen in the present study must have been a juvenile since its length was inferior to 20 cm; by analogy, all the records in Table 2 are of juveniles as well. These records suggest that there may be a spawning-stock biomass of *C. gracilis* in

Tab. 2: Records of *Cubiceps gracilis* ***in the eastern Mediterranean Sea.***
Tab. 2: Zapisi o pojavljanju klateža v vzhodnem Sredozemskem morju.

Area	Date	n	TL (mm)	Depth (m)	References
Sığacık Bay, Aegean Sea	11 September 2005	8	161-180	150-473	Filiz *et al.* (2007)
Gulf of Antalya	1 March 2006	2	165-167	250	Golani *et al.* (2008)
Fethiye Bay, Aegean Sea	17 July 2006	1	100*	10	Irmak *et al.* (2007)
Gulf of Antalya	7 January 2022	1	190	400	This study

* standard length SL

the eastern Mediterranean Sea. In conclusion, the oceanic fish *C. gracilis* is still very rare in the eastern Mediterranean Sea; in fact, the present is only the fourth record of the species in this region.

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POJAVLJANJE KLATEŽA, *CUBICEPS GRACILIS (*NOMEIDAE), V VZHODNEM SREDOZEMSKEM MORJU

Okan AKYOL & Altan LÖK
Ege University Faculty of Fisheries, 35440 Urla, İzmir, Türkiye
e-mail: okan.akyol@ege.edu.tr

Funda ERDEM
Directorate of Agriculture and Forestry, Döşemealtı, Antalya, Türkiye

POVZETEK

Avtorji poročajo o dodatni najdbi klateža, Cubiceps gracilis *(Lowe, 1843), ki kaže na širjenje areala v vzhodno Sredozemsko morje. Sedmega januarja 2022 so v vlečno mrežo na južni turški obali pri Antalyji ulovili primerek klateža na globini približno 400 m. Ta oceanska riba je še vedno zelo redka v vzhodnem Sredozemskem morju, saj gre šele za četrto najdbo, prvo po letu 2006.*

Ključne besede: klatež, nova najdba, meritve, Antalya

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OCCURRENCE OF THE RARE DRIFTFISH *CUBICEPS GRACILIS* (NOMEIDAE) FROM THE ALGERIAN COAST (SOUTHWESTERN MEDITERRANEAN SEA)

Farid HEMIDA & Boualem BRAHMI
École Nationale Supérieure des Sciences de la Mer et de l'Aménagement du Littoral (ENSSMAL), BP 19, Bois des Cars, 16320 Dely Ibrahim, Algiers, Algeria

Christian REYNAUD
Laboratoire Interdisciplinaire en Didactique, Education et Formation, Université de Montpellier, 2, place Marcel Godechot, B.P. 4152, 34092 Montpellier cedex 5, France

Christian CAPAPÉ
Laboratoire d'Ichtyologie, Université de Montpellier, 34095 Montpellier cedex 5, France
e-mail: capape@univ-montp2.fr

ABSTRACT

The authors report the capture of a specimen of driftfish, Cubiceps gracilis, *from the Algerian coast. The present specimen was a female measuring 655 mm in total length (TL) and weighing 1580 g in total body weight. Its description includes some morphometric measurements and meristic counts. This is the first specimen of the species to have been captured in at least 50 years, confirming that it is a rare species in this area.* C. gracilis *is an oceanic epipelagic and mesopelagic species generally inhabiting deep bottoms, and is poorly exploited, due also to its low economic value.*

Key words: *Cubiceps gracilis*, Mediterranean Sea, distribution, habitat, description

PRESENZA DEL RARO CENTROLOFO ALALUNGA *CUBICEPS GRACILIS* (NOMEIDAE) LUNGO LA COSTA ALGERINA (MEDITERRANEO SUD-OCCIDENTALE)

SINTESI

Gli autori riportano la cattura di un esemplare di centrolofo alalunga, Cubiceps gracilis *lungo la costa algerina. Si tratta di una femmina che misurava 655 mm di lunghezza totale (TL) e pesava 1580 g di peso corporeo totale. La sua descrizione include alcune misure morfometriche e conteggi meristici. Questo è il primo esemplare della specie ad essere stato catturato negli ultimi 50 anni, a conferma del fatto che si tratta di una specie rara in quest'area.* C. gracilis *è una specie oceanica epipelagica e mesopelagica che generalmente vive su fondali profondi, ed è poco sfruttata, anche a causa del suo basso valore economico.*

Parole chiave: *Cubiceps gracilis*, Mediterraneo, distribuzione, habitat, descrizione

INTRODUCTION

The driftfish *Cubiceps gracilis* (Lowe, 1843) is a semi-cosmopolitan species found on both sides of the Atlantic (Agafonova & Kukuev, 1990). It is known from the eastern Atlantic coast of Canada (Scott & Scott, 1988), along the eastern Atlantic shores from northern areas to Mauritania, in waters surrounding the Azores, the Canaries and the Madeira Islands (Haedrich, 1986), and downwards as far as the South African coast (Haedrich, 1990).

C. gracilis had been previously reported as only inhabiting the western Mediterranean Basin (Haedrich, 1986) and being uncommon in the Italian seas (Tortonese, 1975; Relini *et al.*, 2017). However, later records have extended its distribution eastward to the Adriatic Sea (Dulčić, 2002), the Aegean Sea (Filiz *et al.*, 2007) and the Levant Basin (Golani *et al.*, 2006).

The species is unknown in the Maghreb shore, off the Tunisian coast (Bradai *et al.*, 2004; Rafrafi-Nouira, 2016), but it occurs off the Algerian coast (Dieuzeide *et al.*, 1954; Refes *et al.*, 2010) and in the Moroccan coast (Lloris & Rucabado, 1998). Routine monitoring conducted throughout the Algerian coast for the past two decades at least and the assistance of experienced fishermen yielded the information that a specimen of *C. gracilis* had been captured in the area. The present paper gives a short description of the specimen, including main morphometric measurements and meristic counts, as well as commenting on the real status of the species in the area and the wider Mediterranean Sea.

MATERIAL AND METHODS

A specimen of *C. gracilis* was captured on 28 April 2009 off Sidi-Fredj, located 30 west of Algiers (36°77′ N and 02°84′ E). It was caught by a bottom

Tab. 1: Morphometric measurements in mm and as a percentages of total length (%TL), meristic counts and weight in gram recorded in the specimen of* Cubiceps gracilis *collected off the Algerian coast.
Tab. 1: Morfometrične meritve v mm in kot delež dolžine telesa (%TL), meristična štetja in teža primerka klateža, ujetega ob alžirski obali.

Morphometric measurements	**Size (mm)**	**Proportion (TL%)**
Total length (TL)	655	100.0
Furk length (FL)	565	86.2
Standard length	525	80.1
Body height	160	24.4
Head length	143	21.8
Pre-first dorsal length	175	26.7
Eye diameter	31	4.7
Meristic counts		
First dorsal fin rays	XI	
Second dorsal fin rays	I + 26	
Anal fin	III + 21	
Pectoral fin	23	
Number of gill rakers	23	
Total body weight (g)	**1580**	

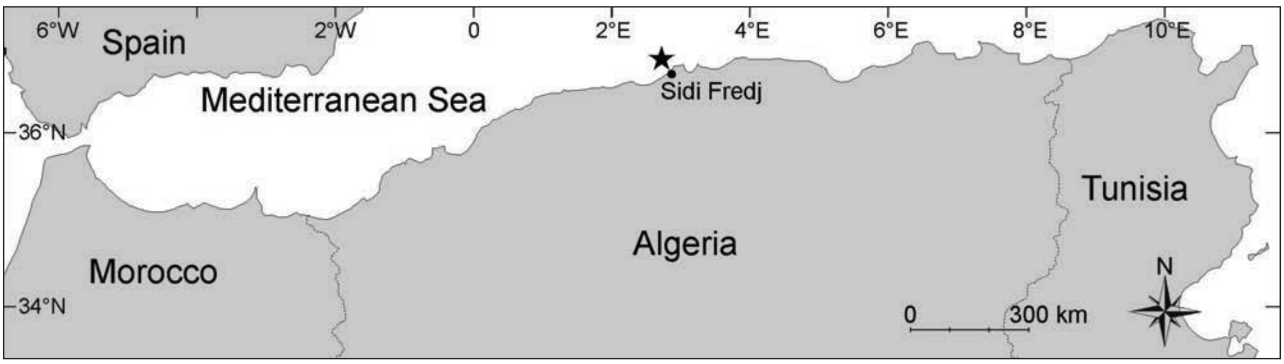


***Fig. 1: Map of the Algerian coast with black star indicating the capture site of* Cubiceps gracilis.**
Sl. 1: Zemljevid alžirske obale z označeno lokaliteto ulova klateža (*Cubiceps gracilis*).

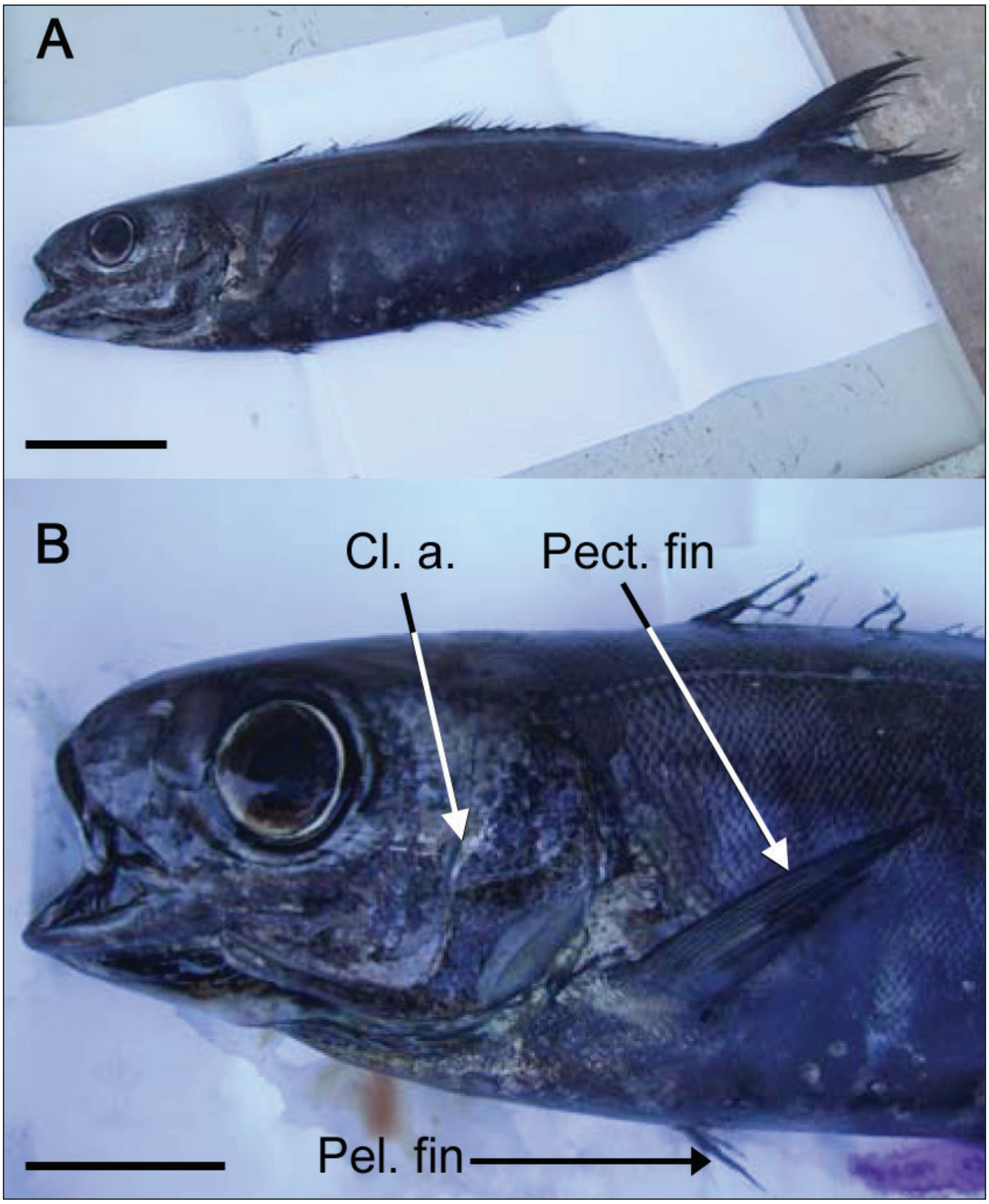


Fig. 2: A. *Cubiceps gracilis* ***collected from the Algerian coast, scale bar = 100 mm. B. Head of the specimen, Cl. A.: clear area, Pect. fin: pectoral fin, Pel. fin: pelvic fin, scale bar = 50 mm.***
Sl. 2: A. Primerek klateža, ulovljen ob alžirski obali, merilo = 100 mm. B. Glava primerka, CL: predel brez lusk, Pect. Fin: prsna plavut, Pel. Fin: trebušna plavut, merilo = 50 mm.

longline at a depth of 150 m approximately, on sandy-rocky substrate. The specimen was measured to the nearest millimetre and weighed to the nearest gram. Morphometric measurements and meristic counts, carried out in the fish market, are presented in Table 1. Unfortunately, the specimen was photographed but not delivered to our laboratory as it was immediately sold by the fisherman who had caught it.

RESULTS AND DISCUSSION

The present specimen measured 655 mm in total length (TL) and weighed 1580 g in total body weight (Fig. 2A). It was a female identified as *C. gracilis* via the combination of the following main morphological characters: body elongated and compressed, caudal fin forked, head and eye large, mouth small reaching back to the vertical of the

anterior of the eye, small single-row conical teeth in both jaws , pectoral fin long and wing-like, the origin of pelvic fins behind pectoral fin base (Fig. 2B), minute and very deciduous scales covering the body and the head almost to the posterior nostril, colour purple brown, fins blackish, small clear areas on the opercular.

The description of the species, including morphological characters, colour and morphometric measurements (see Tab. 1) is in total accordance with Tortonese (1975), Butler (1979), Haedrich, (1986), Quéro *et al*. (2003), Golani *et al*. (2006) and Filiz *et al*. (2007). This finding confirms the occurrence of *C. gracilis* in Algerian waters.

Haedrich (1986) considered *C. gracilis* to be an oceanic epipelagic and mesopelagic species, however, Golani *et al*. (2006) noted that there were individuals of this species caught in the Bay of Antalya, Turkey, using deep water bottom trawl. Filiz *et al*. (2007) reported additional captures of specimens the Aegean Sea, more specifically, Sigacik Bay, Turkey, in fishing grounds located at a depth between 150 and 473 m.

The first records of this species in Algerian waters were of 2 specimens caught in 1950, and a single specimen in 1952, all during the month of April. Refes *et al*. (2010) speculated on the presence of the species in the area, probably based on a literature review, but no specimen was available for confirmation. It appears that the occurrence of *C. gracilis* had not been reported from the Algerian Basin for several decades, six at least. Analogously, since the record of the present specimen, to our knowledge, no subsequent capture of the species has been made in the area, where it could therefore be considered as very rare.

Previous reports of the species show that large specimens were mostly captured in deep waters. Those bottoms are in general poorly exploited by fishermen, but the species is not particularly targeted also because it has a low commercial value. Misidentification with other closely related species cannot be totally ruled out either.

Dulčić (2002) notes that large specimens are rather difficult to capture due to their size and agility that enables them to avoid most nets; conversely, our specimen was caught by a bottom long line. Dulčić (2002) concluded that both distribution and status of *C. gracilis* in the Adriatic Sea should be evaluated carefully and on a continuous basis. Relini *et al*. (2017) pointed to the lack of data on the species despite the fact that it occurs throughout the Italian seas; this lack of data also prevents the determination of the real status of *C. gracilis* in the rest of the Mediterranean Sea, including Algerian waters, where the species is still poorly known.

POJAVLJANJE REDKEGA KLAZEŽA *CUBICEPS GRACILIS* (NOMEIDAE) Z ALŽIRSKE OBALE (JUGOZAHODNO SREDOZEMSKO MORJE)

Farid HEMIDA & Boualem BRAHMI
École Nationale Supérieure des Sciences de la Mer et de l'Aménagement du Littoral (ENSSMAL), BP 19, Bois des Cars, 16320 Dely Ibrahim, Algiers, Algeria

Christian REYNAUD
Laboratoire Interdisciplinaire en Didactique, Education et Formation, Université de Montpellier, 2, place Marcel Godechot, B.P. 4152, 34092 Montpellier cedex 5, France

Christian CAPAPÉ
Laboratoire d'Ichtyologie, Université de Montpellier, 34095 Montpellier cedex 5, France
e-mail: capape@univ-montp2.fr

POVZETEK

*Avtorji poročajo o ulovu primerka klateža (*Cubiceps gracilis*)* z alžirske obale. Bila je samica, ki je v dolžino merila *655 mm in tehtala 1580 g telesne teže. Avtorji podajajo nekatere morfometrične meritve in meristična štetja. Gre za prvi primerek, ki je bil ujet v zadnjih petdesetih letih, kar potrjuje dejstvo, da gre za redko vrsto na tem območju. Klatež je oceanska epipelagična in mezopelagična vrsta, ki se običajno pojavlja v večjih globinah in je zaradi majhne ekonomske vrednosti slabo izkoriščena.*

Ključne besede: *Cubiceps gracilis*, Sredozemsko morje, razširjenost, habitat, opis

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A RARE OCCURRENCE OF *CARAPUS ACUS* (CARAPIDAE) IN THE EASTERN MEDITERRANEAN, TURKEY

Deniz ERGÜDEN & Cemal TURAN
Molecular Ecology and Fisheries Genetics Laboratory, Marine Science Department, Faculty of Marine Science and Technology, Iskenderun Technical University, 31220 Iskenderun, Hatay, Turkey
e-mail: deniz.erguden@iste.edu.tr; derguden@gmail.com

ABSTRACT

Two specimens of pearl fish Carapus acus *(Brünnich, 1768)* *were caught at a depth of 108 m in Gazipaşa coast, Antalya Bay (Eastern Mediterranean, Turkey) in March 2019. The present paper provides information on the occurrence of* C. acus *in the eastern Mediterranean Sea, in Turkey. Since it was recorded only once before in the last twenty-eight years, this species could be considered exceptionally rare in the easternmost area of the Mediterranean Sea.*

Key words: Pearl fish, Carapidae, Rare record, Mersin Bay, Mediterranean Sea

RARO RITROVAMENTO DI *CARAPUS ACUS* (CARAPIDAE) NEL MEDITERRANEO ORIENTALE, IN TURCHIA

SINTESI

Due esemplari di galiotto, Carapus acus *(Brünnich, 1768), sono stati catturati ad una profondità di 108 m al largo della costa di Gazipaşa, baia di Antalya (Mediterraneo orientale, Turchia) nel marzo 2019. L'articolo fornisce informazioni sull'occorrenza di* C. acus *nel Mediterraneo orientale, in Turchia. Poiché precedentemente è stato ritrovato una volta sola negli ultimi ventotto anni, questa specie potrebbe essere considerata eccezionalmente rara nell'area più orientale del Mediterraneo.*

Parole chiave: Galiotto, Carapidae, ritrovamento raro, Baia di Mersin, Mediterraneo

INTRODUCTION

The family Carapidae is represented in Mediterranean waters by a single genus and a single species (Froese & Pauly, 2022), *Carapus acus* (Brünnich, 1768).

Individuals of pearl fish swim close to the sea bottom searching for suitable (new) hosts. The species lives as a commensal in common association with sea cucumbers, spending the day inside the respiratory tree in the body cavity of sea cucumbers (Gonzales-Wangüemert *et al.*, 2014; Froese & Pauly, 2022).

In Turkish waters, the pearl fish has been observed only occasionally (Aksiray, 1954; Geldiay, 1969). It was reported by Gucu *et al.* (1994) from Mersin Bay (northeastern Mediterranean Sea) and later off the Bozcaada Island, in the northern Aegean Sea (Eryılmaz, 2003), as well as from Çeşme (İzmir) in the Turkish coast of the Aegean Sea (Aydın & Akyol, 2018).

Although *C. acus* has been reported in the north coasts of the Levantine Sea (Aksiray, 1954; Gucu & Bingel, 1994), the species is very rare in the Mediterranean (Fischer, 2007). In Turkish Mediterranean waters it had been recorded only once before in the last twenty-eight years. This study reports the first occurrence of *C. acus* from Antalya Bay and confirms the presence of the species in the western area of the southern coasts of Turkey.

MATERIAL AND METHODS

On 28 March 2019, two specimens of *C. acus* were captured at a depth of 108 m with a commercial bottom trawl off the Gazipaşa coast (N 35°47′447″

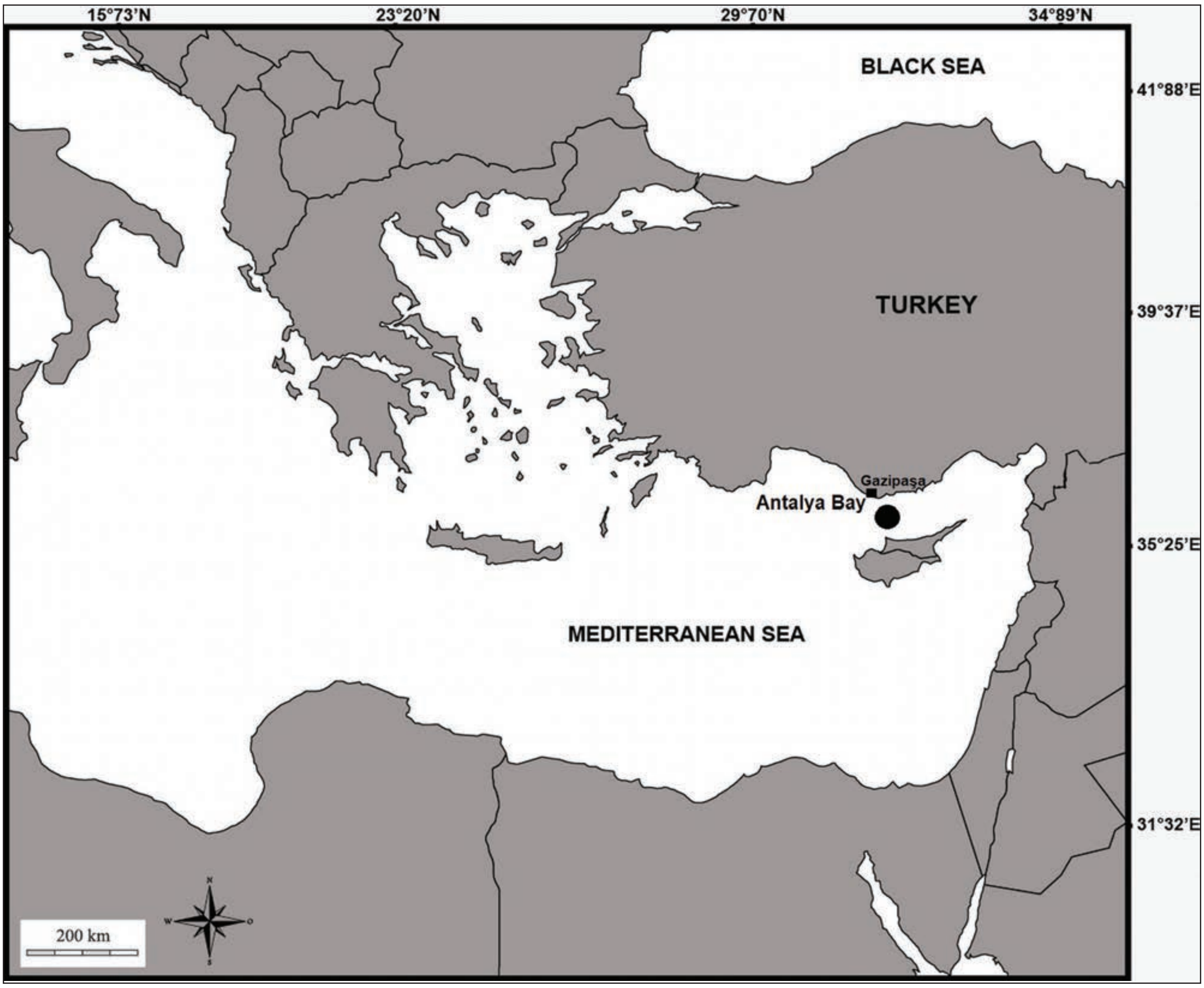


Fig. 1: Map showing the capture site (•) of** Carapus acus **specimens in Antalya Bay (Eastern Mediterranean Sea).
Sl. 1: Zemljevid obravnavanega območja z označeno lokaliteto ulova (•) primerkov strmorinca v Antalijskem zalivu (vzhodno Sredozemsko morje).

Tab. 1: Morphometric measurements of *Carapus acus* ***specimens captured in Antalya Bay, Turkey and comparison with previous studies.***
Tab. 1: Morfometrične meritve osebkov *Carapus acus,* ***ujetih v Antalijskem zalivu v Turčiji, in primerjava s prejšnjimi študijami.***

Measurements (cm)	This study		Enajjar & Bradai (2016)	Aydın & Akyol (2018)
Numbers of Specimens	1	2	1	1
Total length	9.8	8.6	13.6	18.1
Body depth	0.47	0.41	0.54	0.94
Head length	1.34	1.18	1.16	1.33
Head width	0.42	0.37	-	-
Eye diameter	0.24	0.21	0.34	1.67
Pre-orbital length	0.25	0.22	0.33	1.25
Pre-pectoral length	0.70	0.61	1.77	1.27
Pre-dorsal length	1.48	1.30	2.16	4.36
Pre-anal length	1.32	1.16	1.91	1.38

and E 32°45’488’’), in Antalya Bay (western Mediterranean, Turkey) (Fig. 1). After being brought to the laboratory, the specimens were identified and photographed. The morphometric characters of the two specimens were measured to the nearest 0.1 mm using a digital caliper. All measurements and colour agree with the description of Trott & Olney (1986). The specimens were preserved in 4% formaldehyde and deposited in the Museum of the Faculty of Marine Sciences and Technology, Iskenderun Technical University, under catalogue numbers MSM-PIS/2019-4 and MSM-PIS/2019-5 (Fig. 2).

RESULTS AND DISCUSSION

The body is laterally compressed, elongated. The continuous dorsal fin and the anal fin run the whole length of the body. Teeth in jaws small and uniform. There is no caudal fin and the tail ends with a point. Colour*:* the body is translucent, with a number of silvery or reddish-gold iridescent spots on the operculum and the thoracic region. The peritoneum lining the body cavity is an opaque silvery colour.

The pearl fish *C. acus* is a nocturnal species. Adult specimens occurring in shallow waters are typically commensal with holothurian species (Eeckhaut *et al.*, 2004) and generally use them as shelter (Schwartz et al., 2012). The most common sea cucumber hosts are *Parastichopus regalis, H. hammata, H. sanctori*, and *H. tubulosa* (González-Wangüemert *et al.*, 2014). According to Trott & Olney (1986) *C. acus* may partly protrude from or entirely leave the host at night to feed.

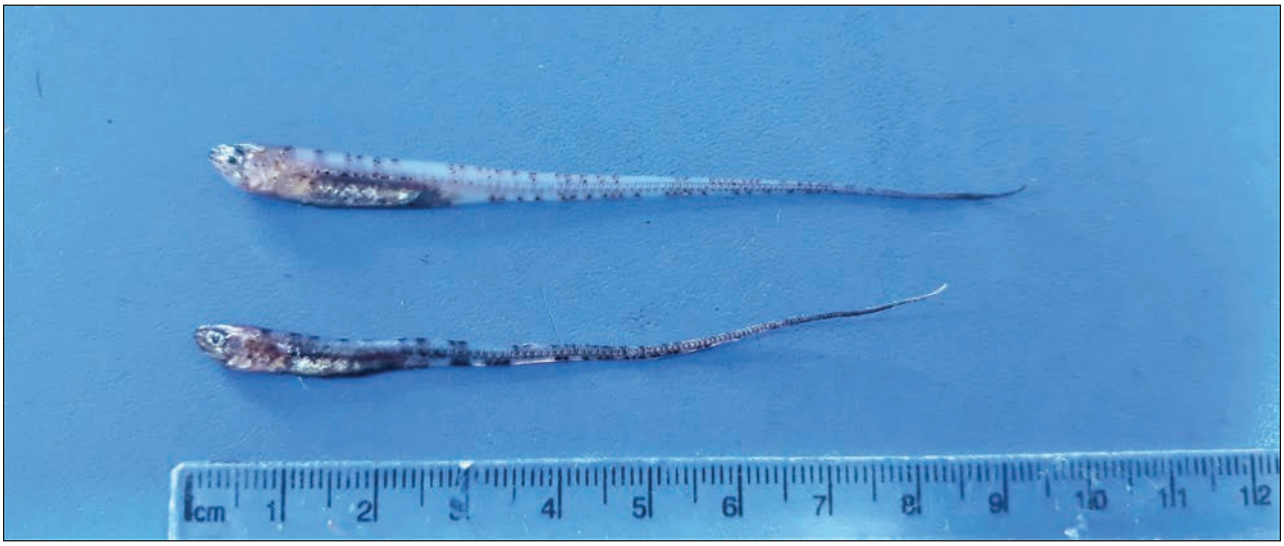


Fig. 2: The specimens of *Carapus acus* ***captured from Gazipaşa coast (Antalya Bay).***
Sl. 2: Primerki strmorincev *(Carapus acus)****, ujeti na obali Gazipaşa (Antalijski zaliv).***

Tab. 2: Records of* C. acus *in the Mediterranean Sea.
Tab. 2: Najdbe strmorincev (*C. acus*) v Sredozemskem morju.

Author(s)	Year(s)	Location	Depth (m)	Gear	TL (cm)
Gucu *et al*. (1994)	May 1980 - October 1984	Northeastern Mediterranean Sea, Turkey	55-78	Trawl net	-
Eryılmaz (2003)	May 2001	Bozcaada Island (northern Aegean Sea), Turkey	68	Trawl net	14.9-16.1
González-Wangüemert *et al*. (2004)	May-July 2013	Off the Southeastern Spanish coast, Spain	-	Trawl net	7.0-21.5
Enajjar & Bradai (2016)	09 May 2014	Gulf of Gabes (central Mediterranean), Tunisia	100	Trawl net	13.6
Aydın & Akyol (2018)	30 March 2018	Çeşme (İzmir) coast (Aegean Sea), Turkey	60-80	Trawl net	18.1
This study	28 March 2019	Gazipaşa coast, Antalya Bay, Turkey	108	Trawl net	8.6-9.8

C. acus is known throughout the Mediterranean, commonly in its western part, and rarely occurs in the Adriatic and the Aegean Seas (Uiblein *et al.,* 2015). It is a non-migratory benthic species found in demersal areas usually at depths between 1 m and 150 m (Nielsen *et al.,* 1999). *C. acus* can reach a maximum size of 20.8 cm in total length, TL (Markle & Olney, 1990). It commonly feeds on small bottom invertebrates and small fishes (Trott & Olney, 1986).

The specimens of pearl fish *C. acus* from Antalya Bay were captured during commercial trawling hauls in the evening, and no sea cucumbers were caught in the process. Gonzales-Wangüemert *et al.* (2014) and Aydın & Akyol (2018) reported *C. acus* specimens found among *P. regalis*. Parmentier and Das (2004) mentioned that these species leave their host holothurians essentially at night. Thus, the two specimens from the present study might have been captured after leaving their hosts.

The two specimens were measured at 8.6 cm and 9.8 cm in TL. The measurements of *C. acus* are summarised in Table 1 and compared with previous Mediterranean samples (Enajjar & Bradai, 2016; Aydın & Akyol, 2018). Our specimens were found to be smaller than those of the previous records reported for the Gulf of Gabes (southern Tunisia, central Mediterranean) (Enajjar & Bradai, 2016), for Bozcaada Island (Aegean Sea, Turkey) (Eryılmaz, 2003), and the Aegean Sea (Çeşme, Turkey) (Aydın & Akyol, 2018). However, González-Wangüemert *et al*. (2004) reported samples for the Mediterranean (southern Spain) that are in total agreement with our measurements. The previous captures of the species in the Mediterranean waters are documented in Table 2.

Although *C. acus* has been categorised as a Least Concern (LC) species in the Mediterranean according to the Red List of the International Union for Conservation of Nature (IUCN), the situation concerning *C. acus* in the Eastern Mediterranean should be re-evaluated. We propose that continuous studies are conducted to further investigate and monitor this rare species in the eastern region of the Mediterranean.

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REDKO POJAVLJANJE STRMORINCA *CARAPUS ACUS* (CARAPIDAE) V VZHODNEM SREDOZEMSKEM MORJU (TURČIJA)

Deniz ERGÜDEN & Cemal TURAN
Molecular Ecology and Fisheries Genetics Laboratory, Marine Science Department, Faculty of Marine Science and Technology, Iskenderun Technical University, 31220 Iskenderun, Hatay, Turkey
e-mail: deniz.erguden@iste.edu.tr; derguden@gmail.com

POVZETEK

Dva primerka strmorinca Carapus acus *(Brünnich, 1768)* *sta bila ujeta na globini 108 m na obali Gazipaşa, v Antalijskem zalivu (vzhodno Sredozemsko morje, Turčija) v marcu 2019. V pričujočem prispevku avtorja podajata podatke o pojavljanju vrste* C. acus *v vzhodnem Sredozemskem morju (Turčija). Ker je bil v zadnjih 28 letih ujet doslej le v enem primeru, to vrsto opredeljujeta kot izjemno redko vrsto v skrajnem vzhodnem delu Sredozemskega morja.*

Ključne besede: strmorinec, Carapidae, redka najdba, zaliv Mersin, Sredozemsko morje

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SKELETAL ABNORMALITIES IN FOUR FISH SPECIES COLLECTED FROM THE SEA OF MARMARA, TURKEY

Laith JAWAD
School of Environmental and Animal Sciences, Unitec Institute of Technology, 139 Carrington Road, Mt Albert, Auckland 1025, New Zealand
email: laith_jawad@hotmail.com

Murat ŞIRIN
Directorate of Provincial Agriculture and Forestry, Ortahisar, Trabzon, Turkey

Miloslav PETRTÝL
Czech University of Life Sciences Prague, Dept. of Zoology and Fisheries

Ahmet ÖKTENER
Food Control Laboratory Directorate, 20010, Merkezefendi, Denizli, Turkey

Murat ÇELIK
Mu la Sıtkı Koçman University, Faculty of Fisheries, 48000, Kötekli, Mu la, Turkey

Audai QASIM
Marine Science Centre, University of Basrah, Basrah – Iraq

ABSTRACT

Skeletal anomalies such as ankylosis (fusion of vertebrae), lordosis (ventral curvature), kyphosis (dorsal curvature) and pugheadedness have been studied in many fish species, both cultured and wild populations. Specimens of Trachurus trachurus *(Linnaeus, 1758),* Mullus surmuletus *Linnaeus 1758,* Serranus hepatus *(Linnaeus, 1758) and* Merluccius merluccius *(Linnaeus, 1758) were collected from the Sea of Marmara (Turkey) and used in this study. Deformities of the vertebral column were located in both thoracic and caudal vertebrae. In the cases of pugheadedness two different levels of severity were observed: secondary level (slight deformation) and tertiary level (severe deformation). The* S. hepatus *specimen displayed the severest level of deformity among the cases studied, ankylosis as well as pugheadedness. All cases were non-fatal as they occurred in adult individuals.*

Key words: Vertebral deformity, ankylosis, lordosis, kyphosis, pollution, environment

ANOMALIE SCHELETRICHE IN QUATTRO SPECIE DI PESCI DEL MARE DI MARMARA, TURCHIA

SINTESI

Anomalie scheletriche come l'anchilosi (fusione di vertebre), la lordosi (curvatura ventrale), la cifosi (curvatura dorsale) e l'ipoplasia della fronte sono state studiate in molte specie di pesci, sia in popolazioni di allevamento che selvatiche. Esemplari di Trachurus trachurus *(Linnaeus, 1758),* Mullus surmuletus *Linnaeus 1758,* Serranus hepatus *(Linnaeus, 1758) e* Merluccius merluccius *(Linnaeus, 1758) sono stati catturati nel Mar di Marmara (Turchia) e utilizzati in questo studio. Le deformazioni della colonna vertebrale erano localizzate in entrambe le vertebre toraciche e caudali. Nei casi di ipoplasia della fronte sono stati osservati due diversi livelli di gravità: livello secondario (deformazione leggera) e livello terziario (deformazione grave). L'esemplare di* S. hepatus *ha mostrato il livello più grave di deformità tra i casi studiati, l'anchilosi così come l'ipoplasia della fronte. Tutti i casi non sono stati fatali in quanto si sono verificati in individui adulti.*

Parole chiave: deformità vertebrale, anchilosi, lordosi, cifosi, inquinamento, ambiente

INTRODUCTION

Fish specimens with morphological deformities are fairly rare but raise concern when encountered, mainly amongst aquaculturists (Buckland, 1863), fishermen, and anglers (Fjelldal *et al*., 2015; Näslund & Jawad, 2021) as well as naturalists and scientists, who often collected them in both private and official collections, either out of interest or for scientific examination (Hickey *et al*., 1977; Heron *et al*., 1988). Abnormalities should be identified as they can be important indicators of pollution or other adverse environmental factors (Klumpp *et al*., 2002; Simon & Burskey, 2016). Therefore, numerous investigators have proposed that abnormalities within fish populations must be supervised as gauges of environmental health in aquatic ecosystems (Lemly, 1997; Sfakianakis *et al*., 2015; Jawad & Ibrahim, 2018).

Among the fish skeletal anomalies often seen and described in several fish groups are ankylosis, lordosis, kyphosis, and pugheadedness. These deformities can be mild or severe both in aquaculture facilities and in the wild (Jawad & Ibrahim, 2018; Näslund & Jawad, 2021). Ankylosis (fusion of vertebrae) can cause deformation of the vertebral bodies either in the form of compression or combination of compression and fusion (Witten *et al*., 2006). Lordosis is perhaps the most well described axis deformity in fishes. It can cause distress in every region of the vertebral axis. It can occur as a pre-haemal lordosis, which has been correlated considerably to the non-inflation of the swim bladder (Chatain, 1994), haemal lordosis, which is a common deformity in fishes (Jawad *et al*., 2014; Fjelldal *et al*., 2009), or cranial (i.e., affecting the most anterior vertebrae) and caudal lordosis (affecting the centra of the caudal peduncle). Kyphosis is considered less common than lordosis (Boglione *et al*., 2013); like lordosis, it can be found in pre-haemal and haemal positions (Boglione *et al*., 1995). Pugheadedness is a noticeable craniofacial skeletal anomaly in fish. It has been known as *brachygnathia superior*, but also referred to as simocephaly, snub-nose, pug-nose, lion-head, bulldog-head, or dolphin-head (Gudger, 1936). Owing to its conspicuity it has drawn specific scientific attention over several centuries (Näslund & Jawad, 2021). Pugheadedness is a brachycephalic anomaly categorised by antero-posterior compression, or hypoplasia, of the forehead. Representative pugheaded fish have brusquely rounded and short foreheads which arch sharply downward just anterior of the eyes, while the lower jaw typically remains normal-like (Branson & Turnbull, 2008; Boglione *et al*., 2013). Several levels of severity of pugheadedness have been defined and specimens displaying the respective deformities reported (Hickey *et al*., 1977; Lemly, 1993; Bueno *et al*., 2015).

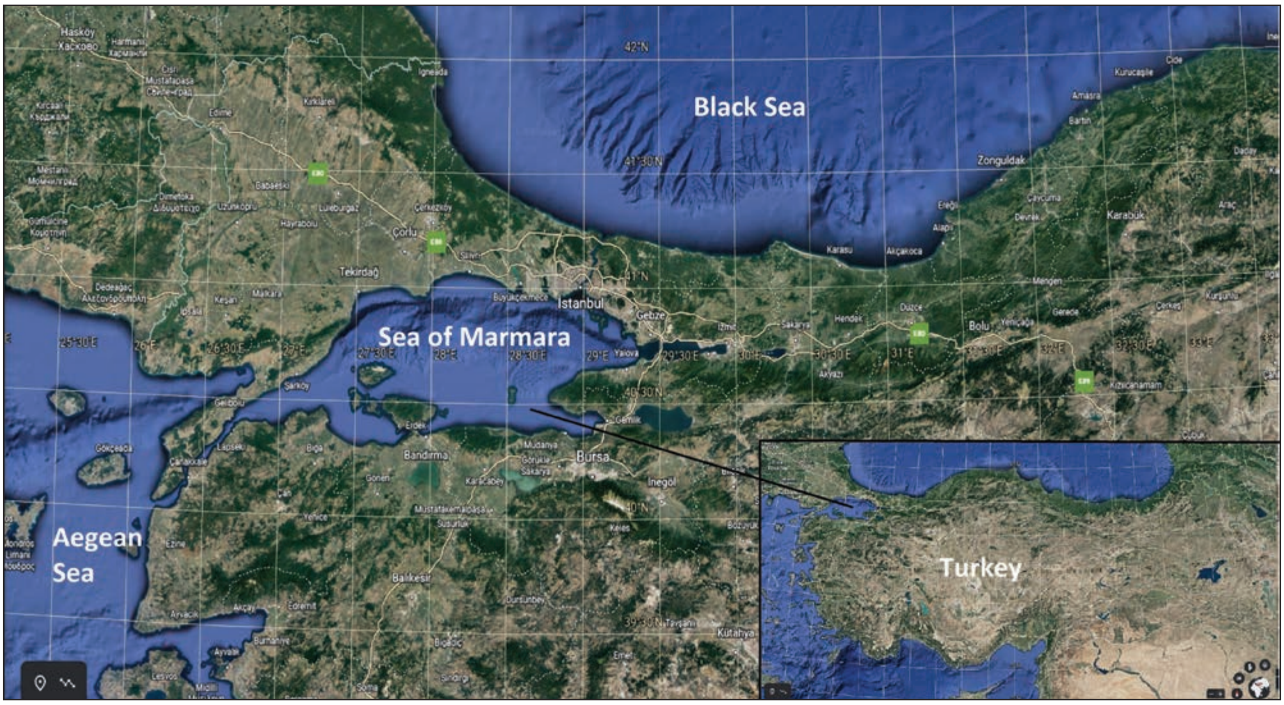


Fig. 1: Map of the study area.
Sl. 1: Zemljevid obravnavanega območja.

The Atlantic horse mackerel, *Trachurus trachurus* (Linnaeus, 1758) is a pelagic-neritic species (FAO 2010-2013), while the surmullet, *Mullus surmuletus* Linnaeus 1758, the brown comber, *Serranus hepatus* (Linnaeus, 1758) and the European hake, *Merluccius merluccius* (Linnaeus, 1758) are demersal species (Mytilineou *et al.*, 2005; Smith, 1981; Muus & Nielsen, 1999). Unlike the brown comber, *S. hepatus,* which has a lower economic value*, T. trachurus*, *M. surmuletus* and *M. merluccius* are all fish of high commercial value. Even in this perspective alone, the health status of these species should be controlled and managed regularly.

For the region of Turkey and the Aegean Sea, cases of lordosis-kyphosis were reported in *M. barbatus* (Jawad et al., 2018b) and pugheadedness in *M. merluccius* (Jawad et al., 2018a). There were no records of ankylosis, lordosis-kyphosis, or pugheadedness in *T. trachurus* and *S. hepatus*. Therefore, the present study is the first to describe a case of ankylosis in a specimen of *S. hepatus*, cases of lordosis-kyphosis in *M. merluccius*, *T. trachurus,* and *M. surmuletus*, and pugheadedness in *M. merluccius*, *T. trachurus,* and *S. hepatus* collected from the Sea of Marmara, Turkey.

MATERIAL AND METHODS

Specimens of *M. merluccius* (3, 188, 243 mm TL), *T. trachurus* (6, 98–160 mm TL), *M. surmuletus* (1, 133 mm TL) *and S. hepatus* (1, 73 mm TL) were collected from different locations (40.37 N 28.13 E, 40.55 N 28.34 E, 40.30 N 28.10 E, and 40.37 N 28.13 E) in the Sea of Marmara in the period 2017–2018 (Fig. 1). All fish specimens were captured by a small commercial trawler operating at depths ranging between 50 and 180 m. In describing the vertebral column of the specimens, all vertebrae lacking haemal spines were called "abdominal vertebrae" and those presenting haemal spines were called "caudal vertebrae." These specimens exhibited lordosis, kyphosis, and pugheadedness. One normal specimen of *M. merluccius* (140 mm TL), *T. trachurus* (117 mm TL), *M. surmuletus* (140 mm TL), and *S. hepatus* (83 mm TL) were obtained for comparison. Specimens' body and fins were examined carefully for malformations, deletions, and any other morphological anomalies. The specimens were fixed in 70% ethanol and deposited in the fish collection of the Department of Fisheries, Sheep Research Institute, Bandırma, Balıkesir, Turkey. The skeletons of both normal and abnormal specimens were examined using an X-ray machine available at the Veterinary Pet Clinic in Turkey. The angle of vertebral deformation was measured from the centre of the deformity, which in the present case was located in the caudal region, using a digital protractor. To assess the degree of abnormality in the anomalous individual, the height of the curvature of the spinal column (HC) was measured. This corresponded with the distance between the tangent to the apical vertebra and a straight line which passed through the base of the two vertebrae limiting the curvature. The measurements were made with a digital caliper to the nearest 0.01 mm. The depth of curvature (DC) was calculated with the following formula using the method by Louiz *et al*. (2007):

$$DC = (HC / SL) \times 100 \text{ (SL = standard length fish)}$$

To describe vertebral shape changes independently of the individual sizes, five ratios from seven vertebral measurements were calculated.

Length ratio = dorsal length of the vertebra/ventral length of vertebra
Width ratio = anterior width of the vertebra/posterior width of the vertebra
Height ratio = dorsal height of the vertebra/ventral height of the vertebra
Thickness ratio = middle line width of the vertebra/ posterior width of the vertebra
Slenderness ratio = dorsal length of the vertebra/ posterior width of the vertebra

The purposes of these five ratios are: length ratio for wedging along vertebral length; width ratio for wedging along vertebral width; height ratio for distortion of amphicoelous shape; thickness ratio for mid-



Fig. 2: A case of pugheadedness and ankylosis in the serranid species** Serranus hepatus**. A, normal specimen, 83 mm TL; B, abnormal specimen, 73 mm TL.
Sl. 2: Primer popačenosti glave in ankiloze pri volčiču (**Serranus hepatus**). A - normalen primerek, 83 mm telesne dolžine; B – primerek z anomalijami, 73 mm telesne dolžine.

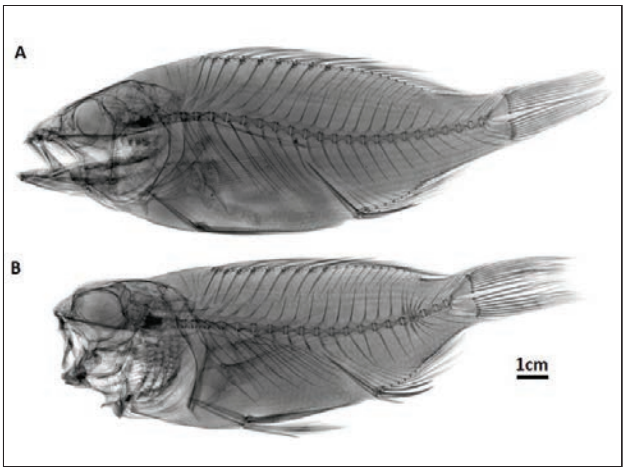


Fig. 3: Radiograph of* Serranus hepatus*. A - normal specimen, 83 mm TL, B - abnormal specimen, 73 mm TL, exhibiting pugheadedness and ankylosis.
Sl. 3: Radiografija primerka vrste* Serranus hepatus*. A - normalen primerek, 83 mm telesne dolžine; B – primerek s popačeno glavo in ankilozo, 73 mm telesne dolžine.



Fig. 4:* Trachurus trachurus*. A - abnormal specimen, 243 mm TL; B - normal specimen, 117 mm TL.
Sl. 4:* Trachurus trachurus*. A - primerek z anomalijami, 243 mm telesne dolžine; B - normalen primerek, 117 mm telesne dolžine.

centrum thickness; and slenderness ratio for ventral slenderness. All measurements were made by the same person and using the same instrument in order to increase the accuracy of the measurements and reduce variability owing to measurement error.

RESULTS

The description of the cases of lordosis-kyphosis in *M. merluccius, T. trachurus* and *M. surmuletus*, and pugheadedness in *M. merluccius, T. trachurus* and *S. hepatus* is provided below.

Ankylosis
Family: Serranidae
Serranus hepatus (Figs. 2 and 3)

This specimen had two deformities, ankylosis at the posterior caudal vertebrae and pugheadedness. Compared externally to the normal specimen of a nearly equal size, the abnormal specimen exhibited a short and stubby caudal peduncle area and a pughead deformity. Pectoral and caudal fins were normal. The lateral line appeared normal. Radiographs showed an incidence of ankylosis in five vertebrae of the posterior part of the caudal region. Caudal vertebrae 7–11 were preserved, the anterior half of the 11th vertebra was lost, the whole centra of vertebrae 8–10 were lost, coalescence of the neural and haemal spines of these vertebrae were preserved, and the anterior half of 11th vertebra was lost. The remaining vertebrae of the vertebral column were normal in shape, but they were directed upwards. The haemal spine of the 3rd caudal vertebra was directed backwards toward the haemal spine of the 4th caudal vertebra instead of downwards.

Kyphosis
Family: Carangidae
Trachurus trachurus (Figs. 4 and 5)

The hump in the anterior part of the vertebral column was the only externally visible physical anomaly (Fig. 4). Compared to the radiograph of the normal specimen, the radiograph of the deformed specimen showed upward arching of thoracic vertebrae (V1-V7), while the descending part of the vertebral column is formed of vertebrae 8–11 (Fig. 5).

The curvature in the vertebral column of the deformed specimen seemed to affect the dimensions of the thoracic vertebrae involved in the arching. Vertebrae 3–6 showed an increased height on the ventral side (0.019–0.021) and reduced height on the dorsal side (1.200–1.201). Vertebrae 1–3 were slightly wedged (1.101–1.110) (having a reduced ventral length compared to the dorsal length). Vertebrae 5–11 had reduced midline widths (0.021–0.025). The amphicoelous centra of vertebrae 2 and 3 were distorted such that the height was increased on the dorsal side (0.001–0.002). Slenderness and thickness were reduced in vertebrae 2–3 (0.001–0.003).

Consecutive repetition of lordosis-kyphosis
Family: Merlucciidae
Merluccius merluccius (Fig. 6)

A radiograph of the deformed specimen showed two lordotic and two kyphotic regions extending along all vertebrae from V1 to V50. Each region involved multiple vertebrae. The vertebrae forming the 1st lordotic arch were V–V12, the 1st kyphotic

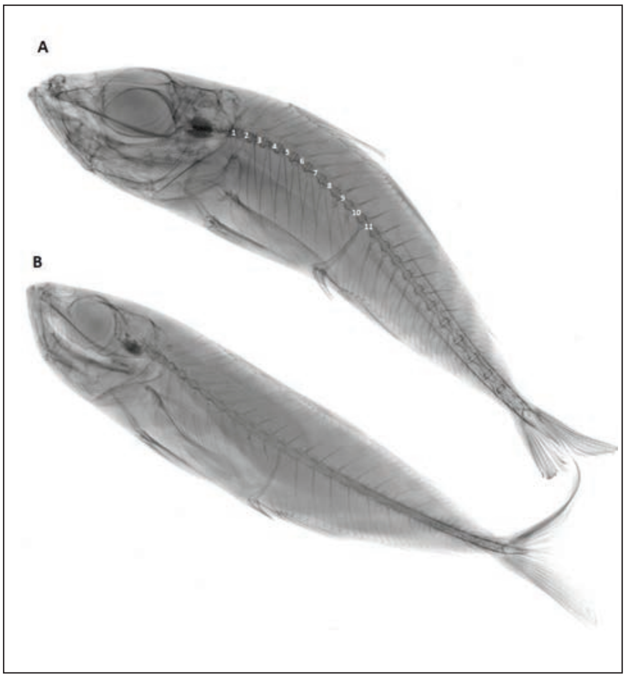


Fig. 5: Radiograph of** Trachurus trachurus**. A - abnormal specimen exhibiting kyphosis, 160 mm TL. The vertebrae involved in the incidence of abnormality are numbered 1–11; B - normal specimen, 117 mm TL.
Sl. 5: Radiografija primerka vrste** Trachurus trachurus**. A - primerek s kifozo, 160 mm telesne dolžine. Vretenca, pri katerih je anomalija izražena, so oštevilčena od 1 do 11; B - normalen primerek, 117 mm telesne dolžine.

arch contained vertebrae 4–20, the 2nd lordotic arch comprised vertebrae 12–29, and in the 2nd kyphotic arch involved vertebrae 20–51 (Fig. 6). The value of the lordotic angle "A" was 146.7°, the kyphotic angle "B" was 152.37°, the lordotic angle "C" was 160.22° and the kyphotic angle "D" was 156.03°. In general, the dimensions of the vertebrae involved in lordosis-kyphosis repetition were not affected. The amplitude of the curvatures of the angles A, B, C, and D were 34.5, 23, 16.1 and 11.5 mm, respectively.

Family: Carangidae
Trachurus trachurus (Figs. 7–8)

There were 4 specimens of *T. trachurus* displaying consecutive recurrence of lordosis-kyphosis, as shown in Figures 7a-d. The spinal deformities in the deformed specimens were visible externally, already upon capture. The severity of the anomalies in the affected specimens ranged from mild in specimen "A," medium in specimens "B" and "C," to severe in specimen "D." No other deformities were detected on the bodies of the deformed fish.

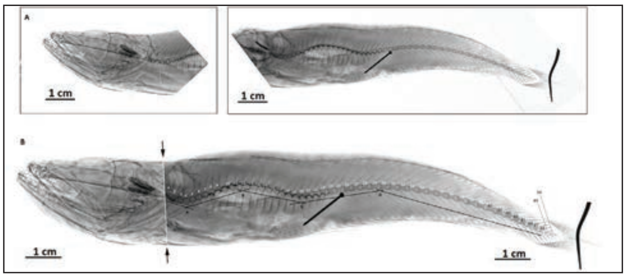


Fig. 6: Radiograph of a** Merluccius merluccius **specimen, 139 mm TL, exhibiting consecutive repetition of lordosis-kyphosis. A - general view of the deformed vertebral column; B - vertebrae (numbered) involved in the incidence of repetition of lordosis-kyphosis.
Sl. 6: Radiografija primerka vrste** Merluccius merluccius**, 139 mm telesne dolžine, s ponavljajočima se lordozo in kifozo. A - pogled na deformirano hrbtenico; B - vretenca (oštevilčena), pri katerih je anomalija izražena.

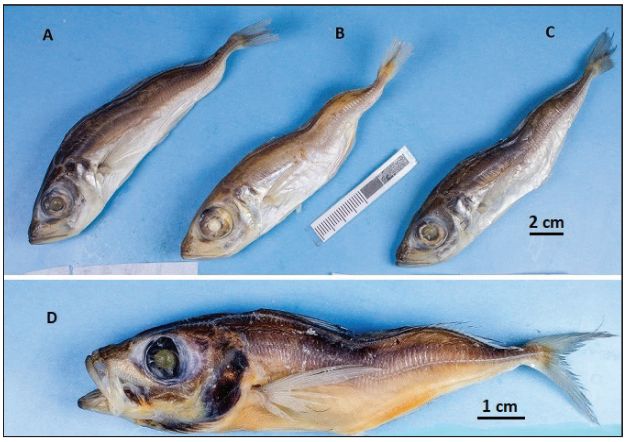


Fig. 7: Specimens (A–D) of** Trachurus trachurus **of different sizes displaying different levels of consecutive repetition of lordosis-kyphosis.
Sl. 7: Različno veliki primerki (A–D) šnjura (**Trachurus trachurus**) z izraženim ponavljanjem lordoze-kifoze.

Radiographs of the four anomalous specimens revealed various recurrence of lordosis and kyphosis. Specimen "A" exhibited two lordotic and two kyphotic arches, specimens "B" and "C" exhibited two lordotic arches and one kyphotic arch, and specimen "D" exhibited one lordotic and one kyphotic arch.

In specimen "A," the vertebrae involved in the 1st kyphotic arch were V1–V9, with V5 at the top centre of the arch. The 1st lordotic arch involved V6–V15, with V10 at the bottom centre of the curve. The 2nd kyphotic arch included V11–V18, with V14 located at the top centre of the arch. The 2nd lordotic arch involved V16–V22, with V19 at the bottom centre of the curve.

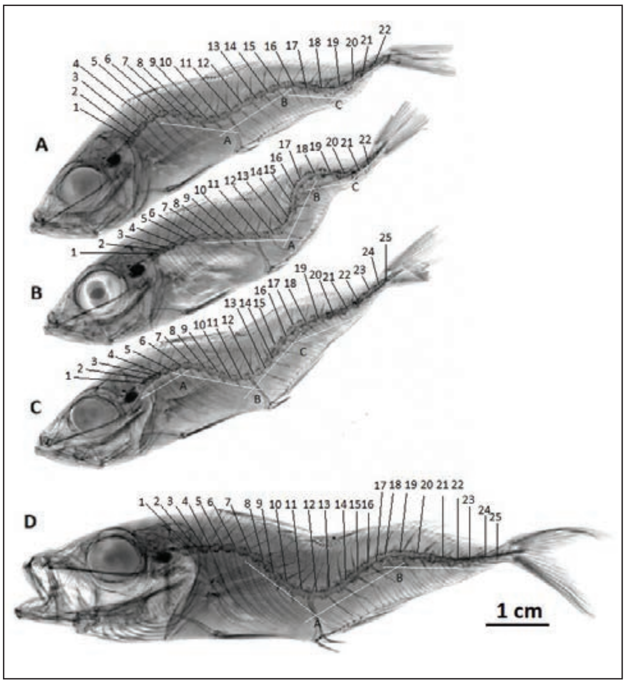


Fig. 8: Radiographs of four specimens (A–D) of** Trachurus trachurus **displaying different levels of consecutive repetition of lordosis-kyphosis. The vertebrae involved in the incidences of abnormality are numbered.
Sl. 8: Radiografije štirih primerkov šnjura (**Trachurus trachurus**) (A–D) izraženim ponavljanjem lordoze-kifoze na različnih nivojih. Vretenca, pri katerih je anomalija izražena, so oštevilčena.

In specimen "B," V7–V16 were included in the 1st lordotic arch, with V12 at the bottom centre of the arch. The 1st kyphotic arch included V13–V20, with V17 located at the top centre of the arch. The 2nd lordotic arch included V18–V22, with V20 at the bottom centre of the arch.

In specimen "C," the 1st kyphotic arch contained vertebrae 1–11, with V6 at the top centre of the arch. The 1st lordotic arch involved V7–V16, with V12 found at the bottom centre of the arch. The 2nd kyphotic arch included V13–V21, with V 17 at the top centre of the arch.

In specimen "D," the lordotic arch involved V7–V18, with V12 situated at the bottom centre of the arch. The kyphotic arch included V13–V22, with V19 positioned at the top centre of the arch.

The values of angles "A," "B" and "C" in specimen "A" were 139°, 138° and 140°, respectively. The values of angles "A," "B" and "C" in specimen "B" were 118.8°, 125.3° and 150°, respectively. The values of angles "A," "B," and "C" in specimen "C" were 140°, 121.5° and 156.2°, respectively. The values of angles "A" and "B" in specimen "D" were 110.8° and 149.7°, respectively.



Fig. 9: Two specimens of** Mullus surmuletus**. A - normal, 140 mm TL; B - abnormal specimen, 133 mm TL, exhibiting consecutive repetition of lordosis-kyphosis.
Sl. 9: Dva primerka progastih bradačev (**Mullus surmuletus**). A - normalen primerek, 140 mm telesne dolžine; B - primerek z izraženim ponavljanjem lordoze-kifoze s telesno dolžino 133 mm.

The depth of the curvatures of the angles "A, B, C" in specimen "A" were 26, 20, 15, and 14 mm, respectively. The depth of the curvatures of the vertebral column A, B, C in specimen "B" were 27, 30, and 15 mm, respectively. The depths of the curvatures of the vertebral column A, B, C in specimen "C" were 26, 27, and 15 mm, respectively. The depths of the curvatures of the angles A and B in specimen "D" were 42 and 21 mm respectively.

The kyphosis-affected vertebrae of the four specimens of *Trachurus trachurus* collected from the Sea of Marmara, Turkey, are shown in Table 1.

Family: Mullidae
Mullus surmuletus (Figs. 9 and 10)

One specimen exhibited consecutive repetition of lordosis-kyphosis. Externally, the fish appeared to have a wide and high hump extending from the anterior to the posterior edges of the dorsal fin. Posteriorly to the soft rays of the dorsal fin, the dorsal edge of the body displayed a notch followed by a lower and shorter hump over the caudal peduncle region. Lateral line scales were disturbed starting from below the notch, and posteriorly directed toward the caudal fin. No other abnormalities were observed.

Compared to that of a normal specimen, the radiograph of the anomalous specimen revealed two lordotic and two kyphotic arches. The 1st lordotic arch involved V6–V14, with V10 at the bottom centre of the arch. The 1st kyphotic arch included V12–17, with V15 at the top of the arch. The 2nd lordotic arch encompassed V15–V19, with V18 at

Tab. 1: The various effects of kyphosis on vertebrae of the four deformed specimens of *Trachurus trachurus* ***collected from the Sea of Marmara, Turkey. V = vertebra.***
Tab. 1: Različni učinki kifoze na vretencih štirih deformiranih primerkov šnjurov *Trachurus trachurus* ***iz Marmarskega morja (Turčija). V = vretenca.***

Specimen	Effect	Site of the vertebrae	Vertebrae affected	Value (mm)
A	Increased height	ventral side	V4, 5, 6, 16 and 19	0.020 – 0.023, 0.021 – 0.022, 0.020 – 0.021, 0.021 – 0.024
B	Increased height	ventral side	V18 and V19	0.022 – 0.023, 0.020 – 0.022
C	Increased height	ventral side	V16 and V17	0.024 – 0.026, 0.019 – 0.021
D	Increased height	ventral side	V18 and V19	0.025 – 0.026, 0.022 – 0.024
A	Reduction	dorsal side	V4, 5, 6, 16 and 19	0.210 – 0.230, 0.221 – 0.224, 0.210 – 0.214, 0.221 – 0.231
B	Reduction	dorsal side	V18 and 19	0.213 – 0.223, 0.214 – 0.216
C	Reduction	dorsal side	V16 and V17	0.217 – 0.221, 0.217 – 0.225
D	Reduction	dorsal side	V18 and 19	0.227 – 0.232, 0.221 – 0.229
A	Wedged	-	V4, 5, 19 and 20	0.345 – 0.365, 0.335 – 0.338, 0.332 – 0.339,0.331 – 0.335
B	Wedged	-	V14 and V15	0.311 – 0.318,0.324 – 0.327
C	Wedged	-	V14, V15, and V20	0.311 – 0.314,0.321 – 0.325
D	Wedged	-	V8 and V14	0.331 – 0.338,0.311 – 0.317
A	Reduced midline	-	V17	0.023–0.027
C	Reduced midline	-	V17	0.024 – 0.28
D	Reduced midline	-	V5, 6, and 7	0.019–0.021,0.021–0.022, 0.025–0.028
A	Less Slenderness & thickness	-	V2 – V10	0.002 – 0.003
B	Less Slenderness & thickness	-	V5 – V12	0.001 – 0.004
C	Less Slenderness & thickness	-	V14 – V19	0.002 – 0.005
D	Less Slenderness & thickness	-	V16 – V23	0.001 – 0.002

the bottom centre of the arch. The 2nd kyphotic arch contained V18–V24, with V21 at the top centre of the arch.

The depths of the curvatures of the angles A, B, C, and D were 4.5, 6.5, 6, and 6.5 mm, respectively. The values of the angles A–D were 100°, 102°, 98°, and 120°, respectively.

The different vertebral calculated ratios appeared to be affected by the position of the vertebra and the curvature of the vertebral column. Vertebrae 8, 9, 14, 15, and 20 showed an increased height on the ventral side (0.022–0.024) and reduced on the dorsal side (0.230–0.236). Vertebrae 14, 15, and 21 were wedged (0.045–0.055) (having a reduced ventral length relative to their dorsal length). Vertebrae 3–6 had reduced midline widths (0.023–0.028).

The centra of the vertebrae 9–13 were compressed and slightly deformed, and their neural spines were displaced.

Tab. 2: Morphometric measurements (mm) of the normal and abnormal specimens of** Serranus hepatus, Trachurus trachurus**, and** Merluccius merluccius **collected from the the Sea of Marmara Sea, Turkey.
Tab. 2: Morfometrične meritve (mm) normalnih primerkov in primerkov z anomalijami vrst** Serranus hepatus, Trachurus trachurus **in** Merluccius merluccius**, ujetih v Marmarskem morju (Turčija).

Species	Status of the specimen	Total length	Standard length	Head length	Preorbital length	Eye diameter	Postorbital length
Serranus hepatus	Normal	83	70.7	28.6	7.1	7.9	11.4
	Abnormal	73.2	57.1	24.3	2.5	7.8	11.3
Trachurus trachurus	Normal	122	98.3	26.7	15.6	15.8	16.2
	Abnormal	193.8	265.6	57.5	12.7	14.4	15.6
Merluccius merluccius	Normal	225.0	192.7	63.6	20.0	13.6	32.9
	Abnormal	281.8	251.8	79.1	15.5	12.7	31.7

Pugheadedness
Family: Serranidae
Serranus hepatus (Figs. 2 and 3)
Family Carangidae
Trachurus trachurus (Figs. 11 and 12)
Family: Merlucciidae
Merluccius merluccius (Figs. 13 - 15)

The abnormal pugheaded specimens of the species *S. hepatus*, *T. trachurus, and M. merluccius* (Figures 2b, 12, and 14a) were compared to respective normal specimens (Figs. 2a, 4b, and 14b). The morphometric measurements of the head in both normal and abnormal specimens are shown in Table 2.

The three specimens that exhibited pugheadedness appeared to have a short neurocranium and upper jaw, and an abnormal (reduced) lower jaw. The snout appeared nearly absent in *S. hepatus*, and moderately present in *T. trachurus* and *M. merluccius*. The mouth in *M. merluccius* was virtually closed by the dropped anterior part of the skull that left only a small opening, but open in *S. hepatus* and *T. trachurus*. In the case of *S. hepatus*, the shortening of the snout had brought the steep forehead close to the eye and moved the anterior nostril ventrally towards the mouth. Most evidently in the case of *S. hepatus*, but to a certain degree also in the specimens of the other two species examined, the head was ball-shaped and tilted upward, resulting in a conspicuous curved area immediately behind it. As a result of the head displacement, the mouth was turned slightly upward in the case of *M. merluccius*, but not in the other two specimens studied.

Compared to normal specimens, the radiographs of the anomalous pugheaded specimens revealed the following deformities: a complete absence of bones of the anterior part of the skull in *S. hepatus*; short vomer, parasphenoid, and maxillaries, displacement and/or curvature of the nasals, frontals, vomer, and palatines in *T. trachurus* and *M. merluccius*; deformed upper jaw teeth in *M. merluccius*. For these reasons, the forehead was upraised and steep in the pugheaded specimen, which in turn exerted pressure on abdominal vertebrae 1-3 making them curve slightly downward (instead of running in a straight line) and stand closer to each other. In the specimens of *T. trachurus* and *M. merluccius*, the otoliths were displaced backwards and appeared to be shorter in length compared to those of normal specimens. In addition, the ventral ends of the three supraneurals located just behind the skull in *S. hepatus* appeared close packed rather than set at equal distances as in the normal specimen.

DISCUSSION

This is the first investigation examining the occurrence and type of vertebral anomalies in the inspected adult wild teleost fish species from the Sea of Marmara, Turkey. The goal was to identify skeletal anomalies and determine a possible relationship between these abnormalities and environmental factors. In the present study, no water analyses were carried out as it is not in the scope of the project that this study is sitting in.

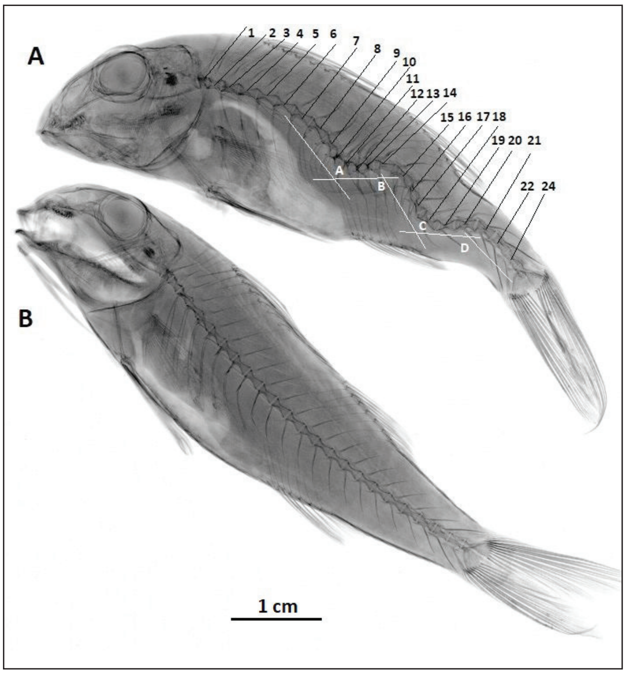


Fig. 10: Radiograph of two specimens of* Mullus surmuletus*. A - abnormal specimen, 133 mm TL, exhibiting consecutive repetition of lordosis-kyphosis. The vertebrae involved in the incidences of abnormality are numbered; B - normal specimen, 140 mm TL.

Sl. 10: Radiografija dveh primerkov vrste* Mullus surmuletus*. A - primerek s telesno dolžino 133 mm TL z izraženim ponavljanjem lordoze-kifoze. Vretenca, pri katerih je anomalija izražena, so oštevilčena; B - normalen primerek, 140 mm telesne dolžine.



Fig. 11: Specimen of* Trachurus trachurus*, 243 mm TL, exhibiting pugheadedness.

Sl. 11: Primerek šnjura s popačeno glavo, 243 mm telesne dolžine.

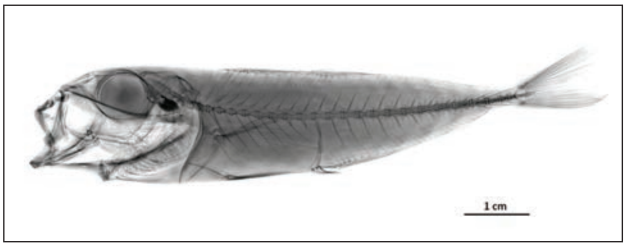


Fig. 12: Radiograph of specimen of* Trachurus trachurus*, 243 mm TL, exhibiting pugheadedness.

Sl. 12: Radiografija primerka šnjura s popačeno glavo, 243 mm telesne dolžine.

There is a considerable number of works on wild fish abnormalities (Divanach *et al.*, 1997; Jawad *et al.*, 2013; Jawad & Liu, 2015) related to deformities. Investigators have studied both genetic (Ishikawa, 1990) and epigenetic issues as conceivable causes of such anomalies (Boglione *et al.*, 1995), as well as environmental features such as temperature, light, salinity, pH, low oxygen concentrations, inadequate hydrodynamic conditions.

In this study, the anomalous specimens presented cases of ankylosis (*S. hepatus*), kyphosis (*T. trachurus*), kyphosis-lordosis (*M. merluccius*, *T. trachurus*, and *S. surmuletus*), and pugheadedness (*S. hepatus*, *T. trachurus*, and *M. merluccius*).

Ytteborg *et al.* (2012) proposes 4 characterising stages of vertebral fusion that may result in spinal fusion (as in the specimen of *S. hepatus*): (i) The early stages in the fusion process are characterised by disordered and proliferating osteoblasts and chordoblasts. (ii) Then, these proliferating cells go through a metaplastic shift: proliferating osteoblasts co-express a mixed signal of both chondrogenic and osteogenic markers and proliferating chordoblasts change transcription to a more osteogenic profile. (iii) As the pathology proceeds, the elastic membrane adjoining the notochord becomes fragmented and the notochordal sheath loses is integrity. (iv) Finally, mineralisation of intervertebral regions and arch centra can be seen.

Evidence from several mammalian investigations has suggested that deviations in the balance between cell death and cell propagation may cause malformations (Kanda & Miura, 2004). The results of the studies of Ytteborg *et al.* (2012) suggest that an augmented development of osteoblasts in progress zones is partially steadied by increased cell death, subsequently, the phase of metaplastic shift to vertebral fusion takes place, followed by a phase of notochordal sheath vitiation, where this sheath was present in a reinstated shape after brief deformation (Yu *et al.*, 2005); consequently, a tear in this sheath might lead to a spinal abnormality.

It is possible that the anomalous specimen of *S. hepatus* was confronted by adverse environmental influences that could give rise to such type of vertebral deformity. Since the specimen reached a sub-adult stage, the anomaly was not deadly; however, it would have definitely affected its mobility in some way when the fish reached adulthood. Except for the distorted caudal peduncle region, the dorsal and anal fins and the remaining fins were found in an apparently perfect state.



Fig. 13: *Merluccius merluccius*. ***A - abnormal specimen, 240 mm TL, exhibiting pugheadedness; B - normal specimen, 188 mm TL.***
Sl. 13: *Merluccius merluccius*. ***A - primerek s popačeno glavo, 240 mm telesne dolžine; B - normalen primerek, 188 mm telesne dolžine.***

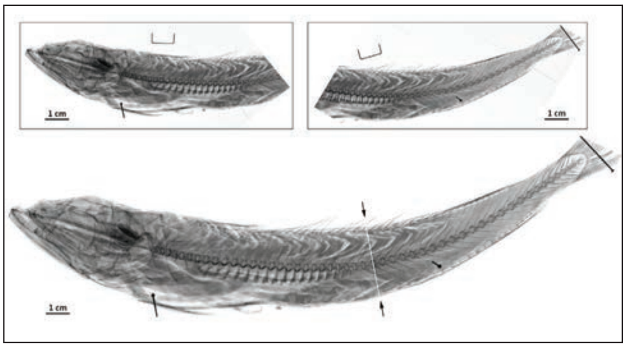


Fig. 14: Radiograph of two specimens of *Merluccius merluccius***, 139 and 188 mm TL, respectively, exhibiting pugheadedness.**
Sl. 14: Radiografija dveh primerkov vrste *Merluccius merluccius***, s telesnima dolžinama 139 in 188 mm, z izraženo popačenostjo glave.**

The variations in the shape of the vertebral column in the incidences of lordosis and kyphosis in the specimens of *M. merluccius*, *T. trachurus* and *S. surmuletus* were linked to the anterior-posterior (i.e., cranial-caudal) compression along the spine. Radiographs of the deformed specimens (Figs. 5, 6, 9, and 11) revealed structural deformations; the normal amphicoelous (hourglass) shape of the vertebrae was distorted, with the vertebral height reduced on the convex and increased on the concave side of the vertebral column. In addition, vertebrae at the approximate bottom centre of the curvature (in the case of a lordotic arch) were wedged, with the length on the concave side of the vertebral column reduced compared to the convex length of the vertebral column. Also, the midline width was significantly lower in some vertebrae. Similar variations were detected in *Poecilia reticulata* by Gorman *et al*. (2010). They suggested that the perceived deviations in vertebral bone structure could be a result of either (1) distortion of normal vertebral shape or (2) active remodelling of vertebral osteoid bone as a consequence of extrinsic forces. They added that vertebral growth in fishes is dissimilar from that of other animal models. The *Poecilia reticulata* which they investigated had vertebrae comprised of acellular bone (i.e., missing entrenched osteocytes and constructed by intramembranous ossification) (reviewed in Witten and Huysseune 2009). Consequently, further investigations of vertebral wedging in *M. merluccius*, *T. trachurus* and *S. surmuletus* as well as other fish species exhibiting lordosis and kyphosis in the future should test cellular activity at the intervertebral region, the presumed growth zone of guppy vertebrae (Inohaya *et al*., 2007), to establish whether there is variation of growth in curved individuals.

The cases of lordosis, kyphosis and consecutive recurrence of lordosis-kyphosis examined in the present study were compared with similar cases in other fish species collected from the Turkish waters. Jawad & Öktener (2007) studied these abnormalities in *Liza* (= *Planiliza*) *abu* collected from Lake Ataturk Dam. Jawad *et al*. (2017a, c) and Jawad *et al*. (2018b) described cases of lordosis, kyphosis, and consecutive repetition of lordosis-kyphosis in the *Atherina boyeri* collected from the Homa Lagoon, Izmir, and in the *Mullus barbatus* and *Mugil cephalus* collected from the northern Aegean Sea, respectively. The case of lordosis and kyphosis seen in the specimens of *Liza* (= *Planiliza*) *abu* and *M. cephalus* were similar in severity to that of specimen "B" of *T. trachurus* described in the present study. The case of *A. boyeri* (Jawad *et al*., 2017c) is similar in severity to that of *T. trachurus* specimen "C." The specimen of *M. barbatus* with consecutive repetition of lordosis-kyphosis described be Jawad *et al*. (2018b) is similar in severity to that of *T. trachurus* specimen "A" described in the present study.

Several authors have shown that bone modelling may be affected by water with reduced oxygen levels through its influence on bone mineral composition (Martens *et al*., 2006). In the waters of the Sea of Marmara in general, the variation in temperature during the years suggests comparable disparity in oxygen levels, with extremely low levels in summer, when the temperature and salinity are at their highest (Keskin *et al*., 2011; Becker *et al*., 2015). Hypoxia, a deficiency of oxygen, is a recognised cause of teratogenic incidences in the musculoskeletal system during embryonic development and during the first larval stage. Hypoxia can also initiate cell apoptosis, a key process in these stages (Shin *et al*,. 2004). During development in fish, sub-lethal hypoxia can increase the incidence of malformations (Eva *et al*., 2004). Cases of hypoxia were reported from different parts of the Sea

of Marmara (Yüksek, 2016; Yalçın *et al*., 2017). Any deformity in the shape of the vertebrae will have a direct effect on the swimming capability of the fish and its survival (Koumoundouros *et al*., 1997), and there a noteworthy correlation between the severity of lordosis and swimming performance has been confirmed in sea bass (*Dicentrarchus labrax*), at least in juveniles (Peruzzi *et al*., 2007).

In teleostean fishes, the severity of pugheadedness can be categorised in three ~~four~~ levels: primary, secondary, and tertiary (Hickey *et al*., 1977). The case of *S. hepatus* represented tertiary-stage pughead anomaly as per the ranking system defined by Hickey *et al*. (1977). The mouth in this specimen was wide open in contrast to the severe cases observed in other fish species, *Johnius aneus* (Al-Hassan & Na'amma, 1988) and *Pagrus auratus* (Jawad and Hosie 2007), in which the mouth was nearly closed. The specimens of *T. trachurus* and *M. merluccius,* exhibited secondary level pugheadedness according to the system of Hickey *et al*. (1977).

Based on an examination of the mouth it was concluded that due to incomplete closure of the mouth the *S. hepatus* specimen could have lost the ability to feed on the food it usually consumed. In contrast, the pugheaded specimens of *T. trachurus* and *M. merluccius* could have been limited in their choice of food items due to the hindered opening of the mouth. Such deformities, in fact, may lead to the inability to contend for food and, consequently, decrease in growth rate (Bortone, 1971; Hickey, 1973). But the present pughead specimens of *T. trachurus* and *M. merluccius* showed no signs of poor health, so feeding was likely unrestricted.

The only works published on the incidence of pugheadedness in fishes from Turkey are by Jawad *et al*. (2017a) on *Nemipterus randalli*, Jawad *et al*. (2017b) on *Pagellus erythrinus* and Jawad *et al*. (2018a) on *Merluccius merluccius*. Specimens of these three species were collected from the Aegean Sea. Based on the descriptions of abnormalities, the case of *S. hepatus* in the present study was similar in severity to that of *N. randalli* described by Jawad *et al*. (2017a), while the cases of *T. trachurus* and *M. merluccius* in the present study were similar in severity to those of *P. erythrinus* and *M. merluccius* described by Jawad *et al*. (2017b) and Jawad *et al*. (2018a), respectively. These similarities may be indicative of two issues: 1) that the environment in both the Aegean Sea and the Sea of Marmara is equally degraded to the point of affecting the development of the fish species living in it. The pugheaded specimens of *M. merluccius* obtained from the Aegean Sea and the Sea of Marmara seem to corroborate that; and 2) a variable degree of vulnerability of fish species to harsh environmental factors. This is evident from the different levels of severity of pughead deformity in the three species examined in the present study, with *S. hepatus* exhibiting tertiary level and *T. trachurus* and *M. merluccius* secondary level of pugheadedness according to the system of Hickey *et al*. (1977).

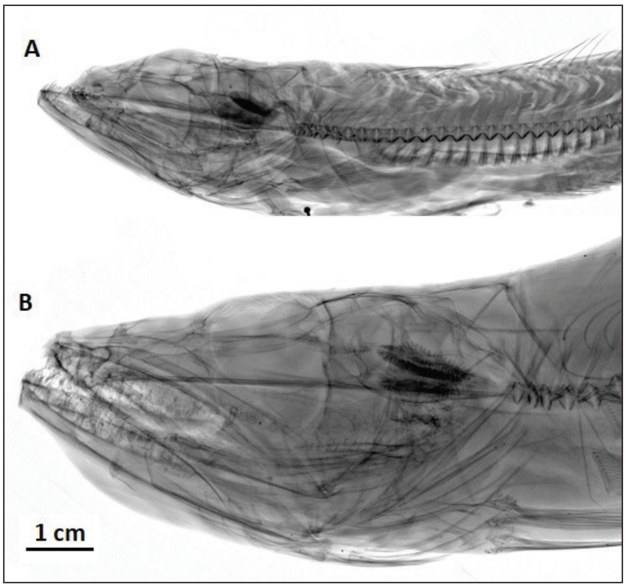


Fig. 15: Radiograph of heads of specimens of *Merluccius merluccius****. A - abnormal specimen, 139 mm TL, displaying pugheadedness; B - normal specimen, 188 mm TL.***
Sl. 15: Radiografija glave primerkov vrste *Merluccius merluccius****. A - primerek s popačeno glavo, 139 mm telesne dolžine; B - normalen primerek, 188 mm telesne dolžine.***

The cause of the manifest pughead deformity in the three specimens of *S. hepatus*, *T. trachurus,* and *M. merluccius* is unknown, but may have originated in early development (Cobcroft *et al*., 2001). Genetic and epigenetic factors can lead to pughead anomaly (Dahlberg, 1970; Sloof, 1982). Mutations or recombination of genes are heritable but not lethal (Browder *et al*., 1993). Contaminants such as trace metals (Nakamura, 1977; Valentine, 1975; Bengtsson, 1991) may be a likely cause as they disrupt the skeletal development by decreasing the concentrations of mobilised calcium and phosphorous within the body and hinder enzymes essential for bone metabolism (Yamashita & Hayashi, 1985; Ludwig *et al*., 1995).

Unlike in hatcheries, the occurrence of pughead deformity in wild fish populations is infrequent. This is potentially because abnormal individuals in hatcheries are sheltered and the predation factor is nil (Bortone, 1971; Riehl & Schmitt, 1985). Consequently, the survival rate and frequency of anomalous individuals among adults there can be higher (Cobcroft *et al*., 2001). Other investigators proposed that such abnormality is recurrent due

to overcrowding (Shariff *et al.*, 1986), xenobiotics (Haga *et al.*, 2003), nutrition (Cobcroft *et al.*, 2001), inbreeding (Sadler & King, 2001) and dietary shortages (Takeuchi *et al.*, 1998).

The economy of the fish catch might be largely affected by the presence of different skeletal anomalies, as such deformities have the potential to reduce the weight of the fish and their value per kg. Consequently, more effort should put in improving the management of the fisheries industries and discovering the aetiological reasons behind the anomalies. Also, in order to assess the economic factors we should ascertain the prevalence of anomaly types in the wild.

CONCLUSIONS

Four types of skeletal abnormalities – ankylosis, lordosis, kyphosis and pugheadedness – were detected in four marine fish species collected from the Sea of Marmara, Turkey. Such anomalies were found in both abdominal and caudal regions of the vertebral column, occurring in mild and severe forms. The *S. hepatus* species appeared more vulnerable to the factors causing such anomalies than other species examined. The results of the present study can be considered as preliminary health status indicators for the environment of the Sea of Marmara and suggest that this sea environment needs to be studied further in terms of pollution in order to accurately determine its condition.

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SKELETNE ANOMALIJE PRI ŠTIRIH VRSTAH RIB IZ MARMARSKEGA MORJA (TURČIJA)

Laith JAWAD
School of Environmental and Animal Sciences, Unitec Institute of Technology, 139 Carrington Road, Mt Albert, Auckland 1025, New Zealand
email: laith_jawad@hotmail.com

Murat ŞIRIN
Directorate of Provincial Agriculture and Forestry, Ortahisar, Trabzon, Turkey

Miloslav PETRTÝL
Czech University of Life Sciences Prague, Dept. of Zoology and Fisheries

Ahmet ÖKTENER
Food Control Laboratory Directorate, 20010, Merkezefendi, Denizli, Turkey

Murat ÇELIK
Muğla Sıtkı Koçman University, Faculty of Fisheries, 48000, Kötekli, Mu la, Turkey

Audai QASIM
Marine Science Centre, University of Basrah, Basrah – Iraq

POVZETEK

Avtorji so raziskovali skeletne anomalije kot so npr. ankiloza (otrdelost sklepov), lordoza (ventralna ukrivljenost), kifoza (dorzalna ukrivljenost) in popačenost glave na štirih vrstah morskih rib. Primerke šnjurov Trachurus trachurus *(Linnaeus, 1758), progastih bradačev* Mullus surmuletus *Linnaeus 1758, volčičev* Serranus hepatus *(Linnaeus, 1758) in osličev* Merluccius merluccius *(Linnaeus, 1758) so za potrebe pričujoče raziskave ulovili v Marmarskem morju (Turčija). Deformacije hrbtenice so ugotovili na prsnih in repnih vretencih. Primere popačenosti glave so ugotovili na dveh različnih nivojih in sicer sekundarnem nivoju (neznatna popačenost) in terciarnem nivoju (huda popačenost). Najbolj izrazite anomalije so opazili pri osebku vrste* S. hepatus, *kjer so ugotovili ankilozo in popačenost glave. Vsi ugotovljeni primeri niso bili smrtno nevarni, saj so se pojavljali pri odraslih primerkih.*

Ključne besede: deformacije vretenc, ankiloza, lordoza, kifoza, onesnaževanje morja, okolje

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RAZMNOŽEVALNA EKOLOGIJA

ECOLOGIA RIPRODUTTIVA

REPRODUCTIVE ECOLOGY

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GONADAL HISTOLOGY IN *DIPLODUS VULGARIS* FROM THE WEST ALGERIAN COAST

Amaria Latefa BOUZIANI
Laboratoire Réseau de Surveillance Environnementale, Département de Biologie, Faculté des Sciences de la Nature et de la Vie, Université d'Oran1, BP 1524 El Menaouar, Algeria

Khaled RAHMANI
University of Ain temouchent BELHADJ Bouchaib, Applied Chemistry Laboratory LACC, Ain temouchent, Algeria
e-mail: khaled46310@gmail.com

Samira AIT DARNA, Alae Eddine BELMAHI, Sihem ABID KACHOUR & Mohamed BOUDERBALA
Laboratoire Réseau de Surveillance Environnementale, Département de Biologie, Faculté des Sciences de la Nature et de la Vie, Université d'Oran1, BP 1524 El Menaouar, Algeria

ABSTRACT

The reproduction of Diplodus vulgaris *in the Algerian west coast was studied between September 2015 and August 2016. Gonadal differentiation and development of males and females were established through histological analysis. Of a total of 472 sampled specimens 246 were females, 206 were males and 20 of undetermined sex. The obtained results show that this species has a clearly defined reproductive period lasting from October to February with a spawning phase in January.*

Key words: *Diplodus vulgaris,* reproduction, ovaries, testicles, west Algeria

ISTOLOGIA GONADICA IN *DIPLODUS VULGARIS* LUNGO LA COSTA ALGERINA OCCIDENTALE

SINTESI

La riproduzione di Diplodus vulgaris *lungo la costa occidentale algerina è stata studiata tra settembre 2015 e agosto 2016. La differenziazione e lo sviluppo gonadico di maschi e femmine sono stati stabiliti attraverso l'analisi istologica. Su un totale di 472 esemplari campionati 246 erano femmine, 206 maschi e 20 di sesso indeterminato. I risultati ottenuti mostrano che questa specie ha un periodo riproduttivo ben definito che va da ottobre a febbraio con una fase di deposizione delle uova a gennaio.*

Parole chiave: *Diplodus vulgaris*, riproduzione, ovaie, testicoli, Algeria occidentale

INTRODUCTION

The two-banded sea bream *Diplodus vulgaris* (Geoffroy Saint-Hilaire, 1817) is easily recognized by a broad triangular black band on the nape of the neck, before the pectoral fins, and another on the caudal peduncle, which extends to the dorsal and anal fins. It is classified among the endemic species of the Mediterranean (Quignard & Tomasini, 2000). Since *D. vulgaris* can be found at variable depths, the capture fishing targeting this species involves a multitude of fishing gear such as trawls, trammel nets, the so-called *charfia* traps, pots, and beach seines (Hadj Taieb, 2018). This work is the first presentation of histological data on the reproduction of the seabream *D. vulgaris* from the west coast of Algeria (North Africa).

MATERIAL AND METHODS

The study of the reproduction of *D. vulgaris* was carried out on a sample of (472) individuals between September 2015 and August 2016, collected at the port of Beni Saf on the west Algerian coast (Fig. 1).

The histology of the gonads of two-banded sea bream was studied on samples collected monthly from the captures by the local fishermen. The research involved a group of 472 individuals, composed of 206 males, 246 females and 20 specimens of undetermined sex.

The study of the microscopic stages consisted in carrying out histological cuts of the gonads after fish dissection. Each collected gonad was preserved in a 10% formaldehyde solution.

The various histological techniques (fixing, dehydration with paraffin embedding, tissue sectioning, staining) were carried out at the Pathological Anatomy and Cytology Laboratory of the Dr. Benzedjeb Hospital in Ain Temouchent (Algeria) following the recommendations by Martoja & Martoja (1967). Slices of tissue 6–7 µm thick were prepared using a microtome, the staining was done with hematoxylin-eosin. All the sections so obtained were then observed under an optical microscope provided with a camera.

RESULTS

The microscopic observation of specimens of both sexes of *D. vulgaris* has made it possible to highlight the evolution of the cells according to the different stages of maturity.

The first stage in females is pre-vitellogenesis, *i.e.*, the differentiation of an oogonium into an oocyte, which is characterized by a homogeneous cytoplasm and a central and bulky nucleus limited by a membrane, which will later be bordered by a zona radiata (Fig. 2A).



Fig. 1: Geographical location of the Bay of Beni Saf on the western coast of Algeria (Rahmani et al., 2021).
Sl. 1: Geografska lega zaliva Beni Saf na zahodni obali Alžirije (po Rahmani in sod., 2021).

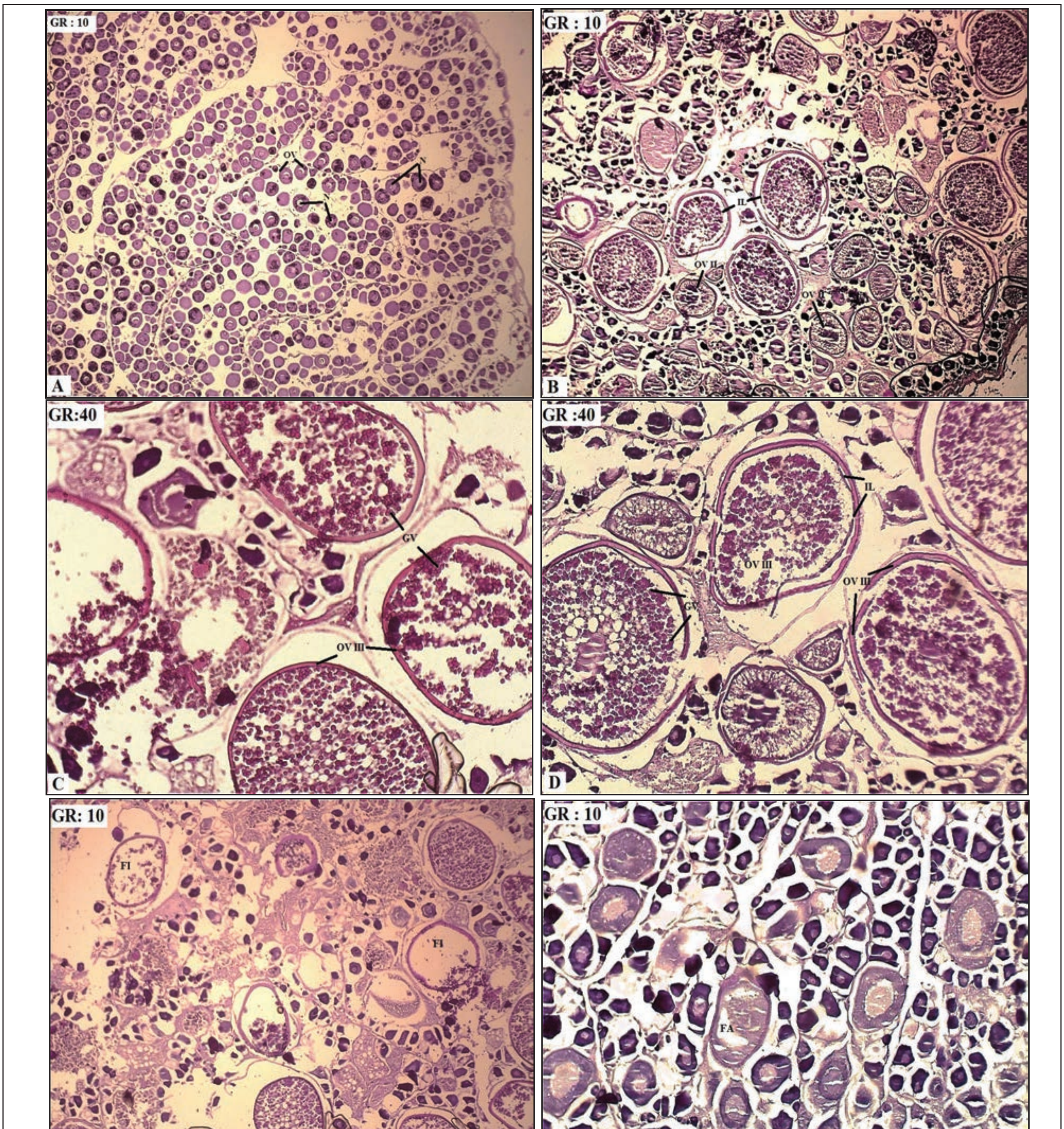


Fig. 2: Histological representation of the four stages of sexual maturity in the females of *Diplodus vulgaris*. ***A: stage I, immature; B: stage II, beginning of maturation; C, D: stage III, maturation and laying; E, F: stage IV, post laying and sexual rest. Ov: oogonium; Lo: lumen of ovary; Il: lipids inclusions; N: nucleus; Gv: vitelline globule; Ov II: oocyte stage II (beginning of maturation); Ov III: oocyte stage III (mature); FL: empty follicle (post-ovulatory gaps); Fa: atretic follicle.***

Sl. 2. Histološki pregled štirih stopenj spolne zrelosti pri samicah fratrov. A: faza I, nezrelo; B: faza II, pričetek zorenja; C in D: faza III, zorenje in izleganje; E, F: faza IV, po izleganju. Ov: oogonij, Lo: lumen ovarija, Il: lipidni vključki, N: jedro, GV: vitelinska kroglica: Ov II: oocitna faza II (začetek zorenja); Ov III: oocitna faza (zrela); FL: prazen folikel (postovulacijska vrzel); atretični folikel.

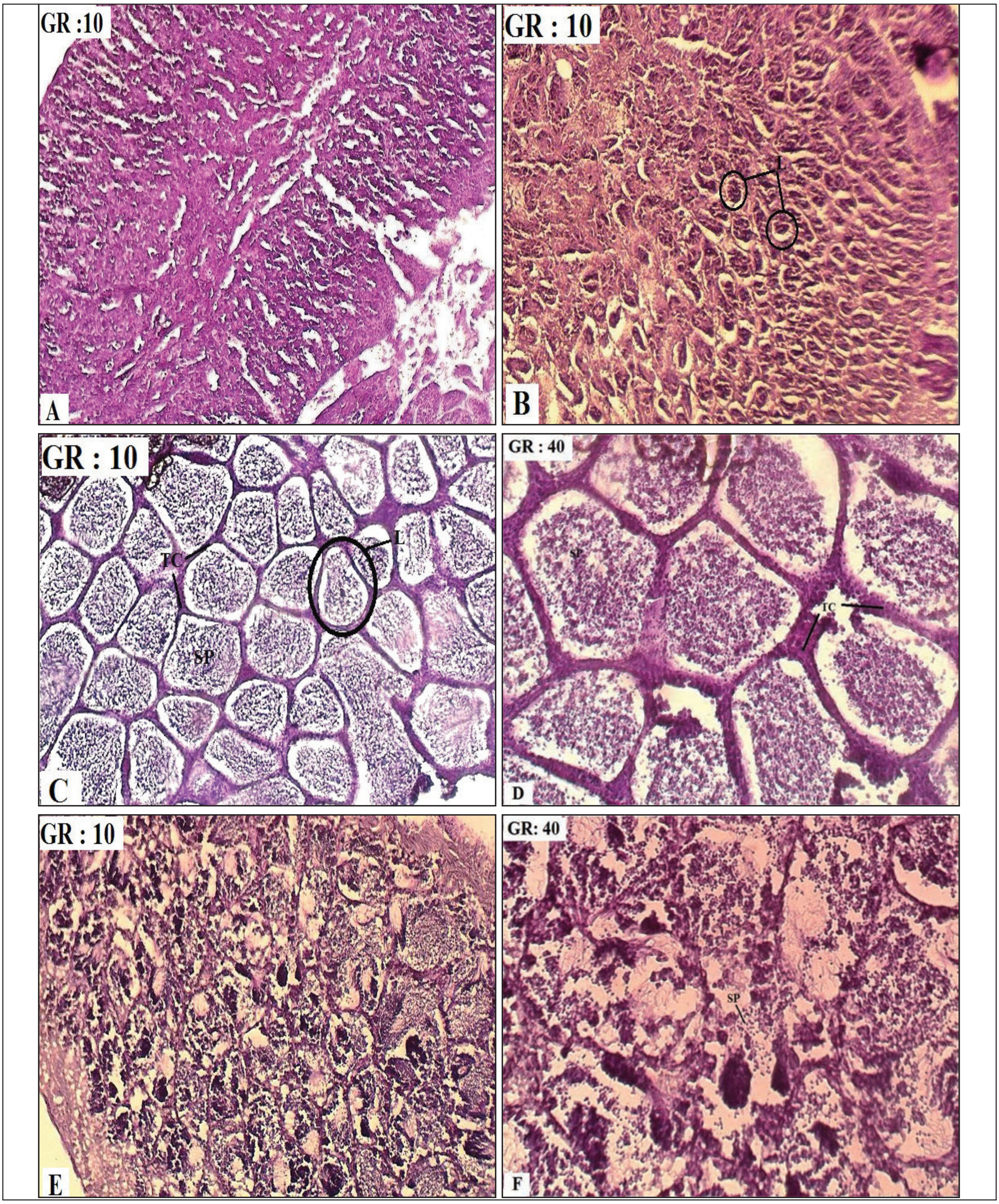


Fig. 3: Histological representation of the four stages of sexual maturity in the males of* Diplodus vulgaris*. A: stage I, immature; B: stage II, beginning of maturation and laying; E, F: Stage IV, post laying and sexual rest. Tc: connective tissue, L: lobule, Sp: sperm.

Sl. 3: Histološki pregled štirih stopenj spolne zrelosti pri samcih fratrov. A: faza I, nezrel; B: faza II, pričetek zorenja in izleganja; E in F: faza IV, po izleganju. Tc: vezivno tkivo, L: lobul, Sp: sperma.

The vitellogenesis stage is characterized by an increase in the size of the oocytes and the deposit of yolk, which will make their cytoplasm increasingly heterogeneous; we also noted the multiplication of follicular cells and thecal cells. In addition, lipid inclusions were observed around the nucleus and at the periphery of the cytoplasm (Fig. 2B).

The end of the vitellogenic stage is marked by hyaline oocytes and followed by the laying, which corresponds to the expulsion of the oocyte wall of its follicular envelope as a result of the destruction of the ovarian follicle wall (Fig. 2C and 2D).

After the laying (Fig. 2E and 2F), any oocytes that are not ovulated will undergo atresia, i.e., degeneration. Only oogonia will remain in the gonads (cellular stock for possible sexual cycles).

The male gonads of *D. vulgaris* are composed of lobules containing cysts filled with spermatogonia. The lobules are separated by connective tissue, during maturation it was observed that the lobules were occupied by cells in advanced spermatogenesis (Fig. 3B, 3C and 3D).

When the wall of the cyst breaks, the sperm floods the spermatic routes. In post-laying the lobules are drained and the lumina narrow (Fig. 3E and 3F).

DISCUSSION AND CONCLUSIONS

According to Konan *et al*. (2020), the gametogenesis in fish transforms the paramount cells into gametes.

Microscopic analysis was essential to determine the maturation of gametes, as the latter cannot be ascertained by the morphological study of the gonads alone.

We studied the histology of the gonads on a random and monthly sample of *D. vulgaris* fished in the Bay of Beni Saf of the west Algerian coast, during the period from September 2015 to August 2016.

Based on the gonado-somatic index (GSI) and macroscopic observations of the gonads we were able to confirm the period of reproduction, as had been previously demonstrated also in a study by Bouziani *et al*. (2018). Our results correspond to those provided by Lechkhab (2007) for the Gulf of Annaba, establishing the period of reproduction for *D. vulgaris* to be between November and February, with the egg-laying phase, i.e., the GSI peaking, in January.

According to Lechkhab and Djebar (2001), before entering the spawning period, the fish undergo a phase of pre-maturation or slow growth, which is characterized by a gradual increase in the value of the gonado-somatic index (GSI). As observed during the phase of maturation, i.e., the pre-laying phase in November and December, the testes start to accumulate increasingly more sperm in the lumina of the seminiferous tubes, whereas the ovaries, containing oocytes at various stages of development, increase in volume owing to the accumulation of vitelline granules.

According to Konan *et al*. (2020), the testicles delimit a conjunctive network containing the sperm. In each conjunctive network a subdivision of germinal cells that have reached the same development stage takes place in the spermatocytes or cysts.

Buslé & Quignard (2004) noticed that after spawning, all the oocytes which are not ovulated will undergo atresia, that is, degenerate and become atretic.

Any sexual cells not reaching maturation, whether male or female, gather and transition to a phase of sexual rest, as previously reported by Cassifour (1975).

Information about reproduction and its peculiarities is one of the most important aspects of studying the biology of a given species. It enables the monitoring of the condition of the exploited stock, its renewal and evolution over time and space.

HISTOLOGIJA GONAD PRI NAVADNEM ŠPARU (*DIPLODUS VULGARIS)* IZ ZAHODNE ALŽIRSKE OBALE

Amaria Latefa BOUZIANI
Laboratoire Réseau de Surveillance Environnementale, Département de Biologie, Faculté des Sciences de la Nature et de la Vie, Université d'Oran1, BP 1524 El Menaouar, Algeria

Khaled RAHMANI
University of Ain temouchent BELHADJ Bouchaib, Applied Chemistry Laboratory LACC, Ain temouchent, Algeria
e-mail: khaled46310@gmail.com

Samira AIT DARNA, Alae Eddine BELMAHI, Sihem ABID KACHOUR & Mohamed BOUDERBALA
Laboratoire Réseau de Surveillance Environnementale, Département de Biologie, Faculté des Sciences de la Nature et de la Vie, Université d'Oran1, BP 1524 El Menaouar, Algeria

POVZETEK

*Avtorji poročajo o raziskavah razmnoževanja pri fratru (*Diplodus vulgaris*) med septembrom 2015 in avgustom 2016 na zahodni obali Alžirije. S histološko analizo so preverjali diferenciacijo in razvoj gonad pri samcih in samicah. Od skupno 472 vzorčenih osebkov je bilo 246 samic, 206 samcev in 20 primerkov nedoločenega spola. Dobljeni rezultati kažejo, da ima ta vrsta jasno opredeljeno obdobje razmnoževanja, ki traja od oktobra do februarja s fazo drstenja v januarju.*

Ključne besede: *Diplodus vulgaris*, razmnoževanje, ovariji, moške spolne žleze, zahodna Alžirija

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THE GROWTH AND REPRODUCTION OF TWO SPARIDAE, *PAGRUS CAERULEOSTICTUS* AND *PAGELLUS BELLOTTII* IN NORTHERN MAURITANIAN WATERS (EASTERN TROPICAL ATLANTIC)

Cheikhna Yero GANDEGA
Laboratory of Ecology & Biology of Aquatic Organisms, Mauritanian Institute for Oceanographic & Fisheries Research, Nouadhibou BP 22, Islamic Republic of Mauritania
e-mail: gandega_cheikhna@yahoo.fr

Nassima EL OMRANI
Laboratory of Aquatic Systems: Marine and Continental Ecosystems, Faculty of sciences, Ibn Zohr University, Agadir, Morocco

Rezan O. RASHEED
College of Science; University of Sulaimani, Kurdistan Region, Iraq

Mohammed RAMDANI
University Mohamed V in Rabat, Scientific Institute, BP 703, Rabat, Morocco
e-mail: ramdanimed@gmail.com

Roger FLOWER
Department of Geography, UCL University College London, London, WC1E, 6BT, UK

ABSTRACT

The paper presents the growth and reproduction parameters for two Sparidae fish species studied in the coasts of northern Mauritania during 2020. The parameters were obtained using a total of 450 indiv. of Pagrus caeruleostictus *and 516 indiv. of* Pagellus bellottii*. The male to female ratio was 52.1% to 47.9% in* P. caeruleostictus *and 53.2% to 46.8% in* P. bellottii*. Sex products were observed from August to October* for P. caeruleostictus*. The spawning period extended from July to December for females and from August to November for males of* P. bellottii*, with a lag of one month between the sexes. Length at sexual maturity in* P. caeruleostictus *was 28.4 cm for males and 28.6 cm for females; and in* P. bellottii *20.04 cm for males and 19.6 cm for females.*

Key words: *Pagrus caeruleostictus*, *Pagellus bellottii,* growth, reproduction, Mauritania

CRESCITA E RIPRODUZIONE DI DUE SPARIDI, *PAGRUS CAERULEOSTICTUS* E *PAGELLUS BELLOTTII*, NELLE ACQUE DELLA MAURITANIA SETTENTRIONALE (ATLANTICO TROPICALE ORIENTALE)

SINTESI

L'articolo presenta i parametri di crescita e riproduzione di due specie di Sparidi delle coste della Mauritania settentrionale, studiati durante il 2020. I parametri sono stati ottenuti utilizzando un totale di 450 individui di Pagrus caeruleostictus *e 516 individui di* Pagellus bellottii*. Il rapporto maschi/femmine era di 52,1%-47,9% in* P. caeruleostictus *e 53,2%-46,8% in* P. bellottii*. Le cellule sessuali sono state osservate da agosto a ottobre per* P. caeruleostictus*. Il periodo di deposizione delle uova si estende da luglio a dicembre per le femmine e da agosto a novembre per i maschi di* P. bellottii*, con un ritardo di un mese tra i due sessi. La lunghezza alla maturità sessuale in* P. caeruleostictus *era di 28,4 cm per i maschi e 28,6 cm per le femmine; in* P. bellottii *20,04 cm per i maschi e 19,6 cm per le femmine.*

Parole chiave: *Pagrus caeruleostictus*, *Pagellus bellottii*, crescita, riproduzione, Mauritania

INTRODUCTION

Knowledge of fishery resources requires the study of its two components (fish biotopes and biocenosis). The bluespotted seabream, *Pagrus caeruleostictus,* is one of the Sparidae species (Orrell *et al.*, 2002). It is commonly found in the Eastern Atlantic and in the Mediterranean Sea (Bauchot & Hureau, 1986; Fischer *et al.*, 1987) at depths ranging from 30 to 200 m (Schneider, 1990; Ismail *et al.*, 2018).

The red pandora (*Pagellus bellottii*) occurs in schools over hard and sandy bottoms, mainly in the upper 100 m. Omnivorous with a predominantly carnivorous diet (including crustaceans, cephalopods, small fish, amphioxi, and worms). Eastern Atlantic from the Strait of Gibraltar to Angola, including the Canary Islands, and southwestern Mediterranean (Bauchot & Hureau, 1986).

The percentages of captures of the two studied species versus other commercial species in the area are 3–5 % depending on the year (Belhabib *et al.*, 2012; Marti, 2018).

Particularly in Mauritania, biological studies on these two species are rather outdated (see Navarro *et al.*,1943; Ikeda & Tetsuya, 1971; Dia *et al.*, 2000a & 2000b; Ould Yarba *et al.*, 2004; Soukhovershin & Ly, 1978–1979; Ndiaye, 2014), hence the need to revise the data. Spawning patterns and reproductive strategy of fish have been mainly considered as part of research aimed at managing the fisheries (Chakroun-Marzouk, 1985; Chakroun Marzouk *et al.*, 1987; Barry *et al.,* 2003 and 2004; Alonso-Fernandez *et al.,* 2008; Ismail *et al.,* 2018).

The size at first sexual maturity is an important parameter for population dynamics as it allows for estimations about the contribution of small fish to the reproduction potential of the stock, about the non-reproductive female composition of samples, and about how to avoid premature captures which can adversely affect reproduction. It should be taken as the absolute minimum catch size for a rational exploitation of the stocks.

This study aims to update data on the growth and reproduction of two Sparidae species, *Pagrus caeruleostictus* (Valenciennes, 1830) and *Pagellus bellottii* (Steindachner, 1882), caught along the Mauritanian coast.

MATERIAL AND METHODS

Both fish species were sampled in the artisanal port of Nouadhibou (NDB) and also collected during sea campaigns for monthly monitoring of the octopus *Octopus vulgaris* by the research vessel Al Awam in the area comprised between 16°40'–17°00'W and 19°10'–21°00'N (Fig. 1).

A total of 450 specimens of *P. caeruleostictus* and 516 specimens of *P. bellottii* were collected from January to December 2020 (ca. 40 specimens per species per month). Individual fish were weighed to the nearest gram (total weight), and total length (TL) and fork length (FL) to the nearest cm. The liver and the gonads were removed and weighed to the nearest 0.01 g using a precision balance (type AE-ADAM STB 62021) and the degree of sexual maturity was determined. After evisceration, each individual carcass was weighed.

Changes in gender percentages (sex ratio) for males and females were calculated for each species. The results were tested by the χ^2 test. Reproduction and growth parameters were studied from January to December 2020. Equation parameters *a* and *b* of the height-to-weight relationship (TW = a * FLb) and the relationship between total length and fork length were established for each sex and for both species.

Sexual maturity was determined according to the macroscopic appearance of the gonads using the Mann and Buxton scale (1998). The sexual cycle of each species was followed through the development of its gonadosomatic index (GSI) calculated according to the formula: GSI = (GW x 100) / EW, where GW = mass of the gonad, and EW = mass of eviscerated fish.

The development of the GSI over time (January to December 2020) enabled the identification of the species' reproductive period. Size at first sexual maturity (L50) was determined using R software and the "FSA,"

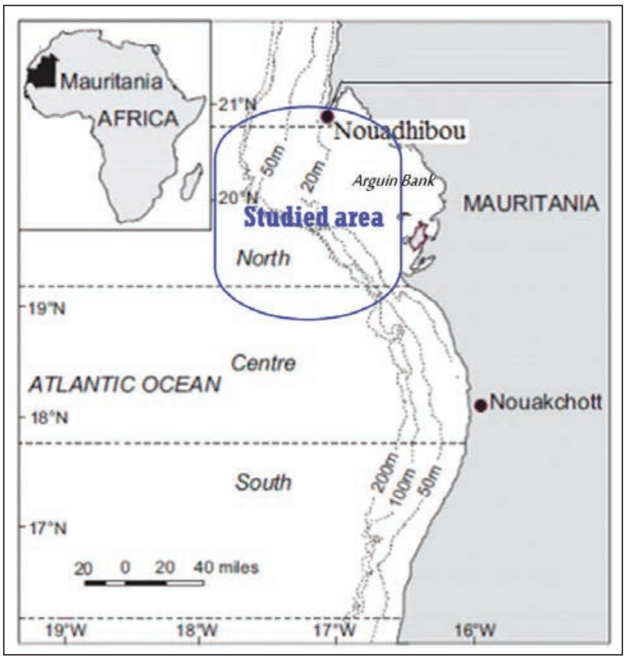


Fig. 1: The coastal region of Mauritania with the study zone (blue box insert).
Sl. 1: Obrežni predel Mavretanije z označenim obravnavanim območjem (modri kvadrat).

Tab. 1: Parameters of the length-weight relationship by species and by sex. TW = Total weight of the individual, EW = eviscerated weight, FL = fork length, (a and b) = parameters of the equation.
Tab. 1: Parametri dolžinsko-masnega odnosa pri obeh vrstah in spolih. TW = celokupna masa primerka, EW = masa brez drobovja, FL = dolžina do vilice, (a in b) = parametri v enačbi.

Species	Sex	TW = a*FLb	R^2	N
Pagrus caeruleostictus	Male	$TW = 0.0004FL^{2.89}$	0.92	234
		$EW = 0.00006FL^{2.81}$	0.91	234
	Female	$TW = 0.00007FL^{2.81}$	0.93	215
		$EW = 0.00007FL^{2.79}$	0.93	215
Pagellus bellottii	Male	$TW = 0.0002FL^{2.971}$	0.88	267
		$EW = 0.00001FL^{3.07}$	0.94	267
	Female	$TW = 0.0001FL^{3.08}$	0.86	235
		$EW = 0.00008FL^{1.74}$	0.85	235

Tab. 2: Total length vs. fork length relationship by species and by sex.
Tab. 2: Odnos med celotno dolžino in dolžino do vilice pri obeh vrstah in spolih.

Species	Sex	A	b	N	R^2
Pagrus caeruleostictus	Males	1.46	0.95	234	0.96
	Females	1.41	0.96	215	0.97
	Indeterminate			1	
	Total of specimens			450	
Pagellus bellottii	Males	1.21	0.98	266	0.94
	Females	1.73	0.92	234	0.95
	Indeterminate			16	
	Total of specimens			516	

"FSAdata" and "CAR" packages. Size L50 corresponds to the fork length at which 50% of individuals in the population are mature. The growth parameters (L_∞ and K) of the two species were obtained by incorporating frequency into the R software and using the "TropFishR" package. This package is based on the FISAT II technique, which uses the Electronic Length Frequency Analysis (ELEFAN) method; it is a system of stock assessment methods based on length frequency (LFQ) data from restructured LFQ data. This method is used to estimate the parameters of the growth model from the progression of LFQ modes over time according to the Von Bertalanffy growth function (VBGF). It is based on the use of the functions available in ELEFAN.

K is the growth curvature parameter, and t_0 is the theoretical age of fish at zero total length.

RESULTS

Length-weight relationship

The sex and weight relationships in these two fish species show quite high correlation coefficients with R-squared value R^2 at 0.85–0.94 for *P. bellottii*

***Tab. 3: Size structure (FL) by sex for** Pagrus caeruleostictus**.*
***Tab. 3: Velikostna struktura (FL) po spolu za vrsto** Pagrus caeruleostictus**.*

FL (cm)	♀	♂	Total	χ^2 ♀	χ^2 ♂	χ2 Total
22-24	2	3	5	0.06	0.06	0.12
25-27	23	25	48	0.00	0.00	0.00
28-30	75	84	159	0.02	0.02	0.03
31-33	69	73	142	0.01	0.01	0.03
34-36	35	34	69	0.12	0.11	0.22
37-39	8	12	20	0.26	0.24	0.50
40-42	3	3	6	0.01	0.01	0.01
Total	**215**	**234**	**449**	**0.48**	**0.44**	**0.92**

***Tab. 4: Size structure (FL) by sex for** Pagellus bellottii**.*
***Tab. 4: Velikostna struktura (FL) po spolu za vrsto** Pagrus bellottii**.*

FL (cm)	♀	♂	Total	χ^2 ♀	χ^2 ♂	χ2 Total
11—12	1	0	1	0.60	0.53	1.14
13-14	0	3	3	1.40	0.00	1.40
15-16	3	4	7	0.02	0.02	0.04
16-18	9	16	25	0.62	0.55	1.17
18-20	15	38	53	3.88	3.41	7.28
20-22	83	108	191	0.46	0.40	0.86
22-24	83	81	164	0.51	0.45	0.96
24-26	32	15	47	4.55	4.00	8.55
26-28	4	1	5	1.18	1.04	2.21
28-30	4	0	4	2.42	2.13	4.55
Total	**234**	**266**	**500**	**15.64**	**12.53**	**28.17**

and 0.91–0.93 for *P. caeruleostictus* (Tab. 1). It is a large positive linear length-weight association with points close to a linear trend line.

Relationship between total length and fork length

To be able to compare our results with those of other authors, we established conversion equations for the different lengths taken into consideration as a function of fork length (Tab. 2). The relationship total length (TL) *versus* fork length (FL) was established per species and per sex. The results (Tab. 2) indicate a slightly low allometry. The growth of the fork length is slower than that of the total length, with a coefficient of determination R^2 varying between 0.94 and 0.97, respectively, for the two species. This rigorous connection between these two metric characters allows use of the fork length in the event of failure in the total length measurement.

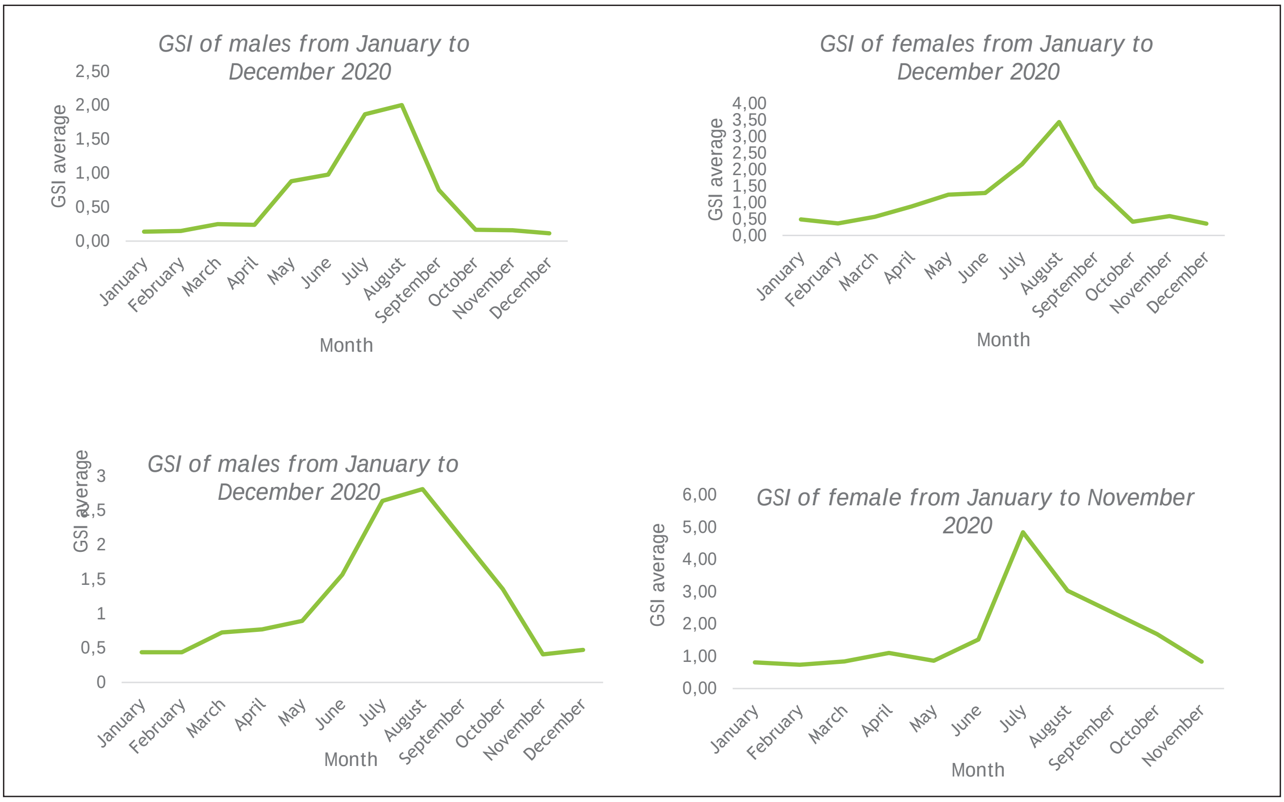


Fig. 2: Monthly evolution of the GSI in** Pagellus bellottii **(top of the graph) and in** Pagrus caeruleostictus **(bottom of the graph).
Sl. 2: Mesečna dinamika GSI pri vrstah** Pagellus bellottii **(vrh diagrama) in** Pagrus caeruleostictus **(spodnji del diagrama).

Sex ratio

The sex ratio is calculated from the total number of individuals collected for each species. In the 450 *P. caeruleostictus* individuals examined, the size varied from 20.6 to 36.5 cm (fork length); 234 specimens were males and 215 females, representing 52% and 48% of the total number, respectively (Tab. 2). In one individual only the sex could not be determined macroscopically. The *P. bellottii* sample was composed of 516 individuals, their size ranging from 14 to 34.8 cm; 266 specimens were males and 234 females, representing 53.2% and 46.8% of the total number, respectively (Tab. 2). The sex could not be determined in 16 individuals. In both species the males outnumbered the females.

Size structure of the two species

To examine the size structure of the two species sampled, χ^2 was applied (Tabs. 3 and 4). The sample size structure analysis of the two species shows that in *Pagrus caeruleostictus* (Tab. 3) there was no significant difference in size between males and females (the calculated χ^2 = 0.92 clearly less than the theoretical value of χ^2, 12.59, at the 5% significance level). In *P. bellottii* the difference in size between the two sexes was significant (the calculated χ^2 = 28.17 exceeding the theoretical value of χ^2, 16.92, at the 5% significance level).

The average size of individuals in a sample can influence its sex ratio; samples containing large specimens most often display a sex ratio favourable to females, conversely, in samples composed mainly of small and medium-sized individuals, males predominate, as was the case with *P. bellottii* (Tab. 4).

Sexual cycle

During the reproduction period, organs, such as the liver and muscles, will provide the energy necessary to maintain the fishes' physiological balance. The reproduction parameters largely control the state of the stock, its renewal and spatio-temporal development. The examination of the monthly variation of the gonadosomatic ratio (GSI) was carried out on a sample of 450 specimens of *P. caeruleostictus* (215 females and 235 males and 1 undetermined) and 516 specimens of *P. bellottii* (234 females, 266 males and

Tab. 5: Summary of the spawning periods for** P. careruleostictus **and** P. bellottii **reported by different authors.
Tab. 5: Pregled podatkov o obdobju drstitve za vrsti** P. careruleostictus **in** P. bellottii **po navedbah različnih avtorjev.

Species	Authors	Area	Spawning period
Pagrus caeruleostictus	Navarro *et al.* (1943)	Mauritanian costs	July - August
	Domain (1979)	Senegales coasts	April – May- August- September and December
	Dia *et al.* (2000b)	Nouakchott (Mauritania)	July – October
	Present study	Nouadhibou (Mauritania)	August – October
Pagellus bellottii	Ndiaye (2014)	Senegales coasts	January to June and August to November
	Present study	Nouadhibou (Mauritanie)	Females: July - December Males: August - November

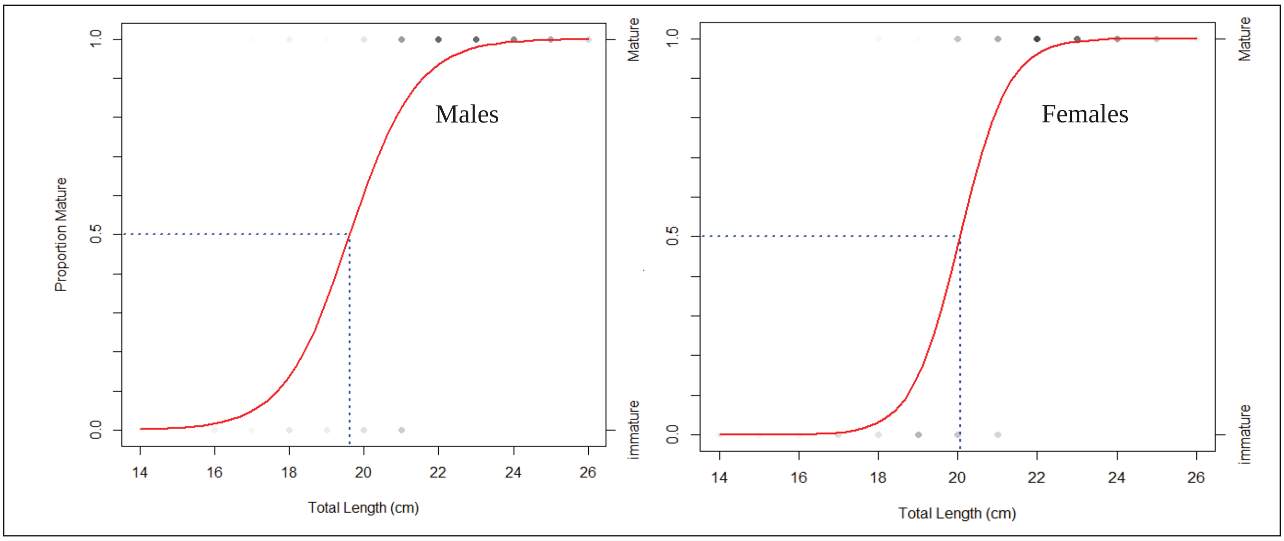


***Fig. 3: Size at first sexual maturity in males (left) and in females (right) for** Pagrus caeruleostictus.*
Sl. 3: Velikost samcev (levo) in samic (desno) vrste** Pagrus caeruleostictus **ob spolni zrelosti.

16 individuals of undetermined sex).

The GSI maturation stages in *Pagrus caeruleostictus* (Tab. 5 and Fig. 2) have been identified as follows:

- The pre-maturation period is from January to April for both sexes.
- The ripening period extends from May to June.
- Spawning and fertilisation takes place from August to October with a coincidental peak in August with release of male products but beginning slightly earlier, in late July.

In *Pagellus bellottii* (Tab. 5 and Fig. 2):

- The pre-maturation period lasts from May to June for females and from March to May for males.
- The maturation period occurs from May to August for males and from May to July for females.
- The spawning period is from July to December with a peak in late July for females, and from August to November with a peak in late July and August for males.

We observed a one-month lag between the reproductive periods of males and females in *P. bellottii*; the release of sex products tends to occur in bursts, which makes this species a batch spawner.

Size at first sexual maturity

Size at first sexual maturity is taken as the length at which 50% of individuals are mature. Maturity is reached by all those individuals whose gonads are at their maximum development and occupy the entire abdominal cavity, corresponding to stages 3 and 4 of Mann and Buxton's scale (1998).

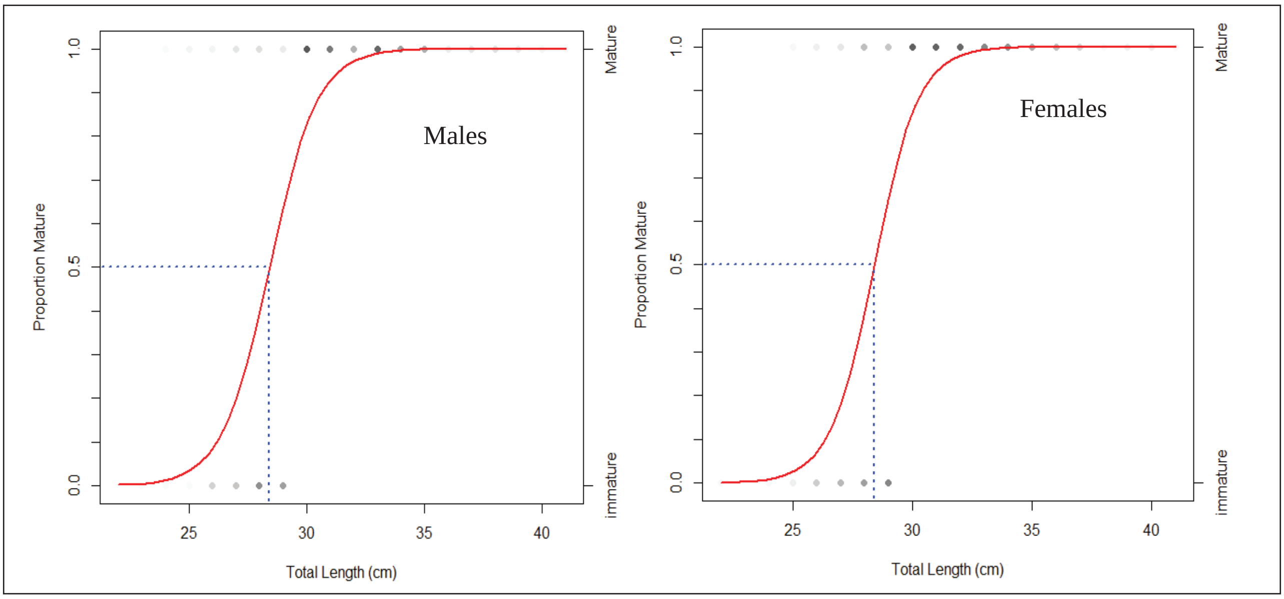


***Fig. 4: Size at first sexual maturity in females (left) and males (right) for** Pagellus bellottii.*
Sl. 4: Velikost samcev (levo) in samic (desno) vrste** Pagellus bellottii **ob spolni zrelosti.

According to generalised linear model results, the length at first sexual maturity (L50) in *P. caeruleostictus* is reached at 28.4 cm in males and 28.6 cm in females, whereas in *P. bellottii* it is reached at 20.04 cm in males and 19.6 cm in females (Figs. 3, 4). The smallest mature male individual in our samples of *Pagrus caeruleostictus* measured 24 cm fork length, the smallest mature female 25 cm. The smallest mature individual in *Pagellus bellottii* was 18 cm in males and 17 cm in females.

Tab. 6: Summary of the parameters of the Von Bertalanffy equation relating to the linear growth of** Pagrus caeruleostictus **and** Pagellus bellottii **from the Mauritanian coast. (FL = fork length; K = growth curvature parameter; t0 = theoretical age of fish at zero total length).
Tab. 6: Pregled parametrov von Bertalanffyjeve enačbe glede linearne rasti pri vrstah** Pagrus caeruleostictus **in** Pagellus bellottii **iz mavretanske obale (FL = dolžina do vilice; K = parameter rastne krivulje; t0 = teoretična starost pri dolžini 0).

Species	Parameters VB			
	Sex	FL∞ (cm)	K	t_0
Pagrus caeruleostictus	Males	48.60	0.1 0	0.23
	Females	47.90	0.16	0.80
Pagellus bellottii	Males	28.00	0.56	0.70
	Females	30.00	4.00	0.50

The large size at first sexual maturity in the two observed sparid species is explained by the fact that the samples were purchased at the artisanal port of Nouadhibou and small individuals are not targeted by commercial fishing.

Growth

Most fish living in temperate waters have seasonal variations in growth related to temperature, feeding, and reproduction (Pajuelo & Lorenzo, 2001; Ndiaye, 2014). The dynamics of the fish population cannot be understood without knowing the growth parameters. Size frequency and sex data for each species examined in this study were entered separately into the R software and used in the "TropFishR" package. The results obtained are shown in Table 6. The results on the growth parameters of both species are slightly different from those by other authors (Tab.7) due to the different methods used and geographical areas covered (Chakroun-Marzouk, 1985).

DISCUSSION AND CONCLUSIONS

According to the results of this study, the *Pagrus caeruleostictus* species does not display any significant difference in proportions of males and females, while in *P. bellottii* the difference is relevant (Tab. 3–4, Fig. 5). Analysis of the spawning period (release of sex product) in *P. caeruleostictus* was carried out from August to October for males and females. The spawning period is shorter in the northern zone than

Tab. 7: Main results on the growth parameters of the two species following different authors.
Tab. 7: Rastni parametri za obe vrsti po navedbah različnih avtorjev.

Species	**Authors**	**Area**	**Methods**	**FL ∞(cm)**	K	**to**
Pagrus caeruleostictus	Chakroun- (1985)	Tunisia	Scalimetry	54 .79	0.20	-0.14
	Dia *et al.* (2000b)	Nouakchott (Mauritania)	Scalimetry	41.19	0.24	-0.74
	Present study	Nouadhibou	Size frequency analysis with R	47.90	0.16	-0.80
Pagellus bellottii	(Mauritania)	Mauritanian coast	Nonlinear adaptation of Maquardt	♀ = 29.7 ♂ = 28.66	0.32 0.28	-0.039 -0.11
	Present study (2020)	Nouadhibou (RIM)	Size frequency analysis with R	♀ = 30 ♂ = 28	4.00 0.56	-0 .5 -0.7

in the southern zone of the Mauritanian exclusive economic zone (July to October) (Dia *et al.,* 2000b, 2001). In *P. bellottii,* the release of sex products occurs from July to December for females and from August to November for males, with one-month lag between the two sexes.

The length at first sexual maturity in *P. caeruleostictus* was 28.4 cm in males and 28.6 cm in females (Tab. 6–7, Fig. 5). In *P. bellottii*, this size is 20.04 cm in males and 19.6 cm in females. The findings on the growth parameters of *P. caeruleostictus* and *P. bellottii* obtained through the method of size frequency analysis using R software, in which the Von Bertalanffy equation relating to growth was incorporated, show an asymptotic length greater in the north zone (L_∞ = 48 cm) than in the south area (L_∞ = 41.19) for *P. caeruleostictus*. A comparison of the populations of *P. caeruleostictus* in the north and south zones indicates better growth of the species in the north zone, which could be explained by the abundance of food in the marine protected area of the Banc d'Arguin (Fig. 1). The temperatures (between 18 and 22°C) of surface and coastal water masses in the study area varied according to the intensity of upwelling during the summer period (Gandega *et al.,* 2016).

The length at first capture proposed by Decree 2015-159 implementing Law No. 017-2015 of 29 July 2015 relating to the Fisheries Code is 23 cm for *P. caeruleostictus* and 19 cm for *Pagellus bellottii*. The results of the present study set the size at first sexual maturity at 28 cm for *P. caeruleostictus* and 20 cm for *P. bellottii*.

Scientific campaigns of the Mauritanian Institute of Oceanography and Fishery (IMROP) have called attention to significant changes in the specific composition of demersal fish catches that have taken place over the last decade. Indeed, noble species such as *Pagrus caeruleostictus* and *Pagelus bellottii* are still present in the captures, but their biomass and sizes of individuals caught have considerably decreased. Stock assessments of these two species have detected overexploitation in the northwest African sub-region since the early 2000s (Barry *et al.*, 2003 and 2004). The results of the FAO working group also indicate that the impact of current fishing efforts on the species is far greater than that which would ensure an optimal long-term yield (FAO, 2006).

The main threat for *P. caeruleostictus* and *P. bellottii* remains demersal fishery, which exclusively targets these very species. But other types of fishing are also contributing to the decline of these species through so-called incidental or "accidental" capture (Belhabib *et al.,* 2012). This is particularly the case for all cephalopod and shrimp trawlers that operate in the marine waters of West Africa, where almost 90% of their accidental catch is made up of these demersal species (Diop *et al.,* 2004).

The biological cycles of the two studied species indicate a single spawning period, which results in a low reproductive potential and a reduced capacity to increase their populations (Pavlidis & Mylonas, 2011). These biological characteristics limit their resilience and their ability to recover from the phenomenon of continuous overexploitation.

However, no specific conservation measure has yet been undertaken in Mauritania to protect these species, apart from indirect conservation measures such as the creation of marine protected areas within their area of distribution, and octopus biological stops, which mainly target the recruitment period and breeding ground for octopus species.

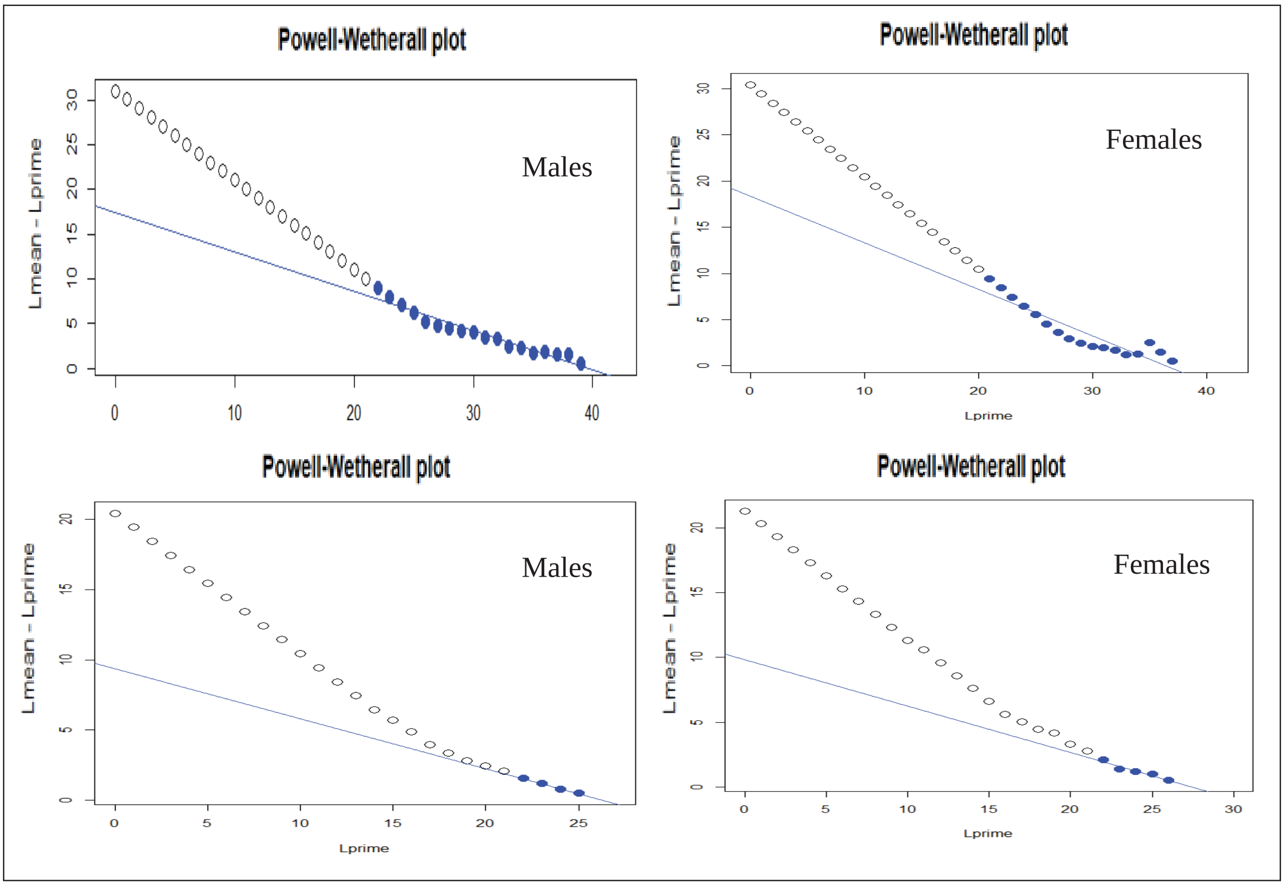


Fig. 5: Estimated mean lengths of** Pagrus caeruleostictus **(top) and** Pagellus bellottii **(bottom).
Sl. 5: Ocenjena povprečna dolžina primerkov za vrsti** Pagrus caeruleostictus **(zgoraj) in** Pagellus bellottii **(spodaj).

Still, even indirect conservative measures represent important protection of the various demersal fish. We strongly recommend their implementation and taking into account the reproduction periods of the two studied species as they have an important commercial value and there should be interest in better managing and preserving demersal resources. In fact, fishery resources are of vital socio-economic interest for the Mauritanian community. The catch is often sold locally for fresh consumption, contributing to the protein balance of many inhabitants, or otherwise processed, frozen, and exported. Hence, fish are nutritionally and commercially important so stocks need to be managed rationally to ensure their sustainability and prevent overexploitation.

RAST IN RAZMNOŽEVANJE DVEH VRST PAGROV, *PAGRUS CAERULEOSTICTUS* IN *PAGELLUS BELLOTTII* V SEVERNIH MAVRETANSKIH VODAH (VZHODNI TROPSKI ATLANTIK)

Cheikhna Yero GANDEGA
Laboratory of Ecology & Biology of Aquatic Organisms, Mauritanian Institute for Oceanographic & Fisheries Research, Nouadhibou BP 22, Islamic Republic of Mauritania
e-mail: gandega_cheikhna@yahoo.fr

Nassima EL OMRANI
Laboratory of Aquatic Systems: Marine and Continental Ecosystems, Faculty of sciences, Ibn Zohr University, Agadir, Morocco

Rezan O. RASHEED
College of Science; University of Sulaimani, Kurdistan Region, Iraq

Mohammed RAMDANI
University Mohamed V in Rabat, Scientific Institute, BP 703, Rabat, Morocco
e-mail: ramdanimed@gmail.com

Roger FLOWER
Department of Geography, UCL University College London, London, WC1E, 6BT, UK

POVZETEK

Avtorji poročajo o parametrih rasti in razmnoževanja za dve vrste iz družine šparov (Sparidae) iz severne Mavretanije v 2020. Analizirali so 450 primerkov vrste Pagrus caeruleostictus *in 516 primerkov vrste* Pagellus bellottii. *Odnos med spoloma je bil (samci: samice) 52,1% - 47.9% pri vrsti* P. caeruleostictus *in 53,2% - 46,8% pri vrsti* P. bellottii. *Spolne celice so opazili od avgusta do oktobra pri vrsti* P. caeruleostictus. *Drstitev vrste* P. bellottii *je potekala od julija do decembra pri samicah in od avgusta do novembra pri samcih, pri čemer je bil časovni zamik med spoloma en mesec. Dolžina samcev vrste* P. caeruleostictus *ob spolni zrelosti je bila 28,4 cm dolžina samic pa 28,6 cm. Pri vrst* P. bellottii *je bila dolžina samcev ob zrelosti 20,04 cm, dolžina samic pa 19,6 cm.*

Ključne besede: *Pagrus caeruleostictus*, *Pagellus bellottii,* rast, razmnoževanje, Mavretanija

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THE REPRODUCTIVE BIOLOGY OF THE POUTING *TRISOPTERUS LUSCUS* FROM THE ATLANTIC COAST OF MOROCCO

Nassima EL OMRANI
Laboratory of Aquatic Systems: Marine and Continental Ecosystems, Faculty of Sciences, Ibn Zohr University, Agadir, Morocco
e-mail: naelomrani007@gmail.com

Hammou EL HABOUZ
Laboratory of Fisheries, National Institute of Fishery Research (INRH), Agadir, Morocco

Abdellah BOUHAIMI & Jaouad ABOU OUALID
Laboratory of Aquatic Systems: Marine and Continental Ecosystems, Faculty of Sciences, Ibn Zohr University, Agadir, Morocco

Abdellatif MOUKRIM
Faculty of Sciences, Abdelmalek Essaadi University, Tetaouan, Mococco

Jamila GOUZOULI
Faculty of Sciences, Ait Meloul, Agadir, Morocco

Mohammed RAMDANI
Department of Zoology & Ecology, Scientific Institute, Mohammed V University of Rabat, Morocco

Roger FLOWER
Department of Geography, UCL - University College London, London, WC1E 6BT, UK

Abdelbasset BEN-BANI
Laboratory of Fisheries, National Institute of Fishery Research (INRH), Agadir, Morocco

ABSTRACT

The reproductive biology of the pouting, Trisopterus luscus*, is not well known in the Moroccan coastal area and this work reports on a two-year study of this species from January 2018 to December 2019. A total of 2210 sampled specimens were examined, of which 1162 were males (52.57%) and 1048 females (47.42%), the males significantly outnumbering the females according to the chi-square test. Monthly monitoring of the gonado-somatic index (GSI) and macroscopic and microscopic gonad observations showed that* T. luscus *was reproductively active throughout the year with maximum peaks during January–February 2018 and March–April 2019. The condition index (K) also peaked in these two months. Changes in the reproductive characteristics of this sampled population of* T. luscus *are discussed in relation to fish size and season and to fecundity.*

Key words: *Trisopterus luscus,* condition index, gonado-somatic index, length at first maturity, Atlantic Moroccan coasts

LA BIOLOGIA RIPRODUTTIVA DELLA BUSBANA BRUNA *TRISOPTERUS LUSCUS* LUNGO LA COSTA ATLANTICA DEL MAROCCO

SINTESI

La biologia riproduttiva della busbana bruna, Trisopterus luscus*, non è ben conosciuta nell'area costiera marocchina e questo lavoro riporta uno studio biennale sulla specie da gennaio 2018 a dicembre 2019. Sono stati esaminati 2210 esemplari campionati, di cui 1162 maschi (52,57%) e 1048 femmine (47,42%), con una significativa prevalenza dei maschi sulle femmine secondo il test del chi-quadro. Il monitoraggio mensile dell'in-*

dice gonado-somatico (GSI) e le osservazioni macroscopiche e microscopiche delle gonadi hanno mostrato che T. luscus *è stato attivo dal punto di vista riproduttivo durante tutto l'anno, con picchi massimi nei mesi di gennaio-febbraio 2018 e marzo-aprile 2019. Anche l'indice di condizione (K) ha raggiunto un picco in questi due mesi. I cambiamenti nelle caratteristiche riproduttive della popolazione campionata di* T. luscus *sono discussi in relazione alle dimensioni e alla stagione dei pesci e alla fecondità.*

Parole chiave: *Trisopterus luscus,* indice di condizione, indice gonado-somatico, lunghezza alla prima maturità, coste atlantiche del Marocco

INTRODUCTION

Knowledge of the reproductive biology of important fish species is essential for successful fishery management (*e.g.*, Birkland & Dayton, 2005; Zhang, 2021). There is increasing awareness that the traditional indicators of stock viability are inadequate because it is the capacity of a fish population to produce viable eggs and larvae each year that is crucial for stock viability and recovery (Kraus *et al.,* 2002; Murua *et al*., 2003). Accurate estimates of the population reproductive potential are also required to assess stock-recruitment relationships (Marshall *et al*. 1994).

The pouting *Trisopterus luscus*, a teleost of the Gadoid family, is of commercial importance for artisanal fleets of a number of European countries, primarily France, Portugal, and Spain, and of major commercial importance on the Atlantic coast of the Iberian Peninsula (*e.g.*, Wheeler, 1978; Whitehead *et al*. 1986). The species' range extends from the North Sea, along the Atlantic coasts of western Europe to the southern Atlantic coast of Morocco and into the Mediterranean Sea. Information concerning this species is relatively scarce but there have been studies on its growth (Puente 1988; Merayo & Villegas 1994), distribution, fish assemblage (shoaling or species composition including age structure) and selectivity (Fonseca *et al*., 2005), feeding ecology, and parasitology (Tirard *et al.,* 1996; Fowler *et al*., 1999).

T. luscus is considered a batch spawner (Merayo, 1996a) with a protracted spawning season during winter and spring time (Desmarchelier, 1985; Gherbi-Barre, 1983; Merayo, 1996a). This pouting undergoes asynchronous ovarian development and females reach maturation at about 15 cm, based on histology (Alonso-Fernández, 2011). Despite the asynchronous ovarian organization, several authors consider *T. luscus* as a species with determinate fecundity, claiming it is possible to estimate its potential fecundity (Alonso-Fernández *et al*., 2008; Merayo, 1996a). However, other data about this species – on growth, for instance – remain sparse (Puente, 1988; Merayo & Villegas 1994).

The pouting is most frequent in coastal areas of the Bay of Biscay, but in the North Atlantic/North Sea it does not extend far northwards beyond the Shetland Islands (El Omrani *et al.,* 2021; Wheeler, 1978). According to Wheeler (1978), the great Norwegian coast acts as the northern barrier for the species. The



Fig. 1: Essaouira-Sidi Ifni sampling area for T**risopterus luscus **and key fishing ports in the central and southern Moroccan Atlantic coastal area.
Sl. 1: Zemljevid obravnavanega območja s predelom Essaouira-Sidi Ifni in glavnimi ribiškimi pristanišči, kjer so bila opravljena vzorčenja vrste** Trisopterus luscus **v osrednjem in južnem maroškim atlantskim obalnim območjem.

important spawning areas for the species appear to be the English Channel (Chevey, 1929), Bay of Biscay, and south to Morocco. Inner coastal areas are preferred spawning areas; according to anecdotal accounts the adult fish move out of these sites and form shoals of homogenous sizes (20–40 cm), while the larger fish prefer rocky areas (Desmarchelier, 1986).

Although the pouting is of major commercial importance on the Atlantic coast of the Iberian Peninsula, it has received little scientific attention as it is not highly valued. Since the fish does not keep well, it must be consumed within a short time after capture. Nevertheless, in France attempts are being made to exploit this fish as a substitute for molluscan and crustacean foods (Desmarchelier, 1986). Knowledge of the pouting's reproductive biology is generally limited and this reproductive study of *T. luscus* is the first to be carried out for Moroccan Atlantic waters.

The Moroccan Atlantic coast is among the richest in exploitable biological resources (El Omrani *et al.*, 2021). The shelf is characterized by the upwelling of deep Atlantic waters that contribute nutrients promoting primary productivity in superficial waters and increasing the productivity of the whole trophic food chain. Indeed, the Moroccan coast has the privilege to be among the five known zones in the world that are influenced by this beneficial upwelling phenomenon. A sequence of physical, chemical, and biological processes encourages primary production and increases the biomass of fish resources, thus, in order to maintain this productivity, continued upwelling of rich deep waters to the surface is essential.

These circumstances prompted the present study on the reproductive biology of *T. luscus*, probably the most complex aspect of this fish's biology. The purpose of this work was to study the reproductive parameters, the sex ratio, the laying period, and the size at first sexual maturity of the Moroccan population of *T. luscus* using both macroscopic and microscopic observations of the gonads. The combination of these reproductive parameters with those of growth and exploitation will help formulate management measures for a rational exploitation of the stock.

MATERIAL AND METHODS

Samples were collected once a month between January 2018 and December 2019 from trawler landings at a port on the Moroccan Atlantic coast (Fig. 1). A total of 2210 individuals were sampled, ranging from 11 to 31 cm in total length. The following information was collected from each individual: total length (L), total weight (Wg), maturation stage, gonad weight (GW), and liver weight (LW). For each mature individual, the gonadosomatic-index (GSI), hepatosomatic-index (HSI) and condition factor (K) were estimated as follows:

$$GSI = GW/W*100 \quad HSI = LW/W*100 \quad K = W/L3*100$$

The sex ratio was calculated monthly according to the following equation: sex ratio = (F/M), M: number of males, F: number of females. The sex ratio was analyzed using a 1-centimeter length class basis.

To follow the developmental processes, the ovaries (n = 400) were removed from specimens for histology and fixed immediately in buffered Davidson preservative. Central portions of the fixed ovaries were extracted, dehydrated, embedded in paraffin, sectioned at 5 µm, and stained with haematoxylin-eosin for microscopic analysis performed through observation and photography of different stages using a camera (ToupCam™) attached to a light microscope (Olympus CX41). For each female, the follicles (oocytes and surrounding follicular layer) were classified into developmental stages based on histological criteria (Saborido-Rey & Junquera, 1998; Murua & Saborido-Rey, 2003). The stages assigned were primary growth, cortical alveoli, vitellogenesis, and hydrated. Other ovarian structures such as atretic oocytes and postovulatory follicles (POFs) were identified and their presences scored for every slide. Female maturity status was determined based on the most advanced oocyte development stage contained within the ovary, the presence of POFs, and percentage of vitellogenesis atresia (Dominguez-Petit, 2007).

All females with ovaries in above-defined maturity stages were considered mature. Females were considered immature when only primary-growth stage oocytes were present and there was no evidence of prior spawning activity, e.g., thick ovary wall.

Macroscopic observations classified female oocytes into five stages (I, II, III, IV, and V) (Holden & Raitt, 1974). Stage I and II oocytes were considered immature; the other stages mature. To define female maturity in terms of body length, a logistic equation was applied to the maturity-at-length data, based on the histological and macroscopic maturity classification methods:

$$P = 1 / (1+e-(a + b * L)) \quad (1)$$

where: P = percentage of mature individuals by size class; L = total length (mm); "a" and "b" = constants. Parameters "a" and "b" were obtained by a logarithmic transformation of the expression (1) which enabled the linear equation (2):

$$Ln (P / (1-P)) = a + b * L \quad (2)$$

Length at first sexual maturity was defined as the length at which 50% of the individuals were mature (L50), i.e., L50 = -a / b (3).

Tab. 1: Relation between macroscopic evolution of ovaries and microscopic evolution of oocytes.
Tab. 1: Povezava med razvojem ovarijev na makroskopskem nivoju in razvojem oocit na mikroskopskem nivoju.

Maturation stage of the ovaries	Macroscopic state of the ovaries	Microscopic evolution of oocytes
1. Immature	Ovary small and pink, homogeneous appearance	Numerous oogonia and oocytes grouped in islands, which are separated by a thin conjunctive blade weft
2. Start of development	Pink ovary, size between 4 and 5cm	Scarce oogonia, appearance of increasing oocytes
3. Vittelogenesis	Orange-coloured ovary, grainy appearance. A few hyaline oocytes are visible through the ovarian membrane	All stages of maturation are present: oocytes in the process of vitellogenesis are the most abundant
4a. Pre-spawning 4b. Spawning	a. The presence of many hyaline oocytes gives the ovary a speckled appearance. b. Significant vascularization of the ovarian membranes. Eggs begin to be released	a. The presence of many hyaline oocytes gives the ovary a speckled appearance. b. Significant vascularization of the ovarian membrane. Eggs begin to be released
5. Post-spawning and recovery	Flaccid and yellowish ovary, wrinkled envelope, numerous non-emitted oocytes still occupy the ovary. The ovary takes on its immature appearance	Disorganized ovary; numerous empty follicular envelopes which are reabsorbed. Abundant blood cells and atresia of all vitellogenic oocytes that were not been emitted

Oocyte diameter distributions

Ovarian histology was supplemented by analysis of the frequency distributions of diameters of the oocytes contained in the ovary. This study allowed us to ascertain whether spawning takes place at one time or several times during a single sexual cycle: strategy of laying (Le Duff, 1997). According Kartas & Quignard (1984), seasonal egg spawning, when examined in terms of size distribution of eggs in the ovary, may respond to one of the following models:

- Bimodal (or multimodal) distribution of eggs in which the laying of the most advanced group is followed by the development and laying of one or more groups developed from the secondary groups;
- Bimodal distribution of eggs in which the most advanced group is laid and the next secondary group resorbed. *T* resembles unimodal distribution except for the oocytes maturing again within the annual sexual cycle allowing a second spawning;
- Unimodal distribution of eggs, corresponding to a single laying per season (concentrated or spread over time);
- Unimodal distribution of eggs laid immediately before or after a secondary group derived from the development of cells without vitellus.

Batch fecundity and relative fecundity: according to Bagenal (1966), batch fecundity is the number of eggs ripening in a female just before laying, whereas Aboussouan & Lahaye (1979) define it as the number of oocytes destined for laying. The method of studying individual absolute fecundity that we adopted was that of "volume sampling" as used by many authors (Simpson, 1951; Bagenal, 1966). The mature stage IV ovaries were collected from 30 females of *T. luscus*.

After a histological confirmation that the diameter of the oocytes was homogeneous between the 3 median, posterior, and anterior parts of the ovary and between the 2 ovary lobes, a sample was collected from the ovary central area and weighed in grams to two decimal places. Samples were stored in a neutralized 10% formaldehyde solution. This method gives better results than the one using Gilson's liquid, as it and makes it possible to dissociate connective tissue of the ovary and thus isolate the oocytes, essential for subsequent counts. In the case of environment procedure, Gilson's fluid is renewed about every 10 days to promote the dissociation of the oocytes. The latter can be accelerated by frequent agitation of samples stored in pill boxes.

After separating the stroma, the oocytes were washed with fresh water to remove excess formalin and concentrated detritus from the supernatant. They were then diluted with 1 liter of salt water. Mechanical homogenization of the liquid column was required before removing 1 ml of subsamples using a graduated pipette. This subsample was then counted using a Dollfus tank. This operation was repeated 3 times for each ovary sample and the absolute in-

Tab. 2: Annual sex ratio of* T. luscus *in the Moroccan Central Atlantic coastal area from January 2018 to December 2019.
Tab. 2: Letno razmerje med spoloma pri vrsti* T. luscus *na maroškem obalnem območju srednjega Atlantika od januarja 2018 do decembra 2019.

Year	N	Females	Males	Females (%)	Males (%)
2018	1391	539	852	39%	61%
2019	819	509	310	62%	38%
2018-2019	2210	1048	1162	47%	53%

dividual fecundity was determined according to the formula of Le Bec (1985): F = n (Vd / Vse) x (Pg / Pe), where F = batch fecundity; n = mean of the 3 subsamples; Vd = dilution volume (ml); Vse = volume of a subsample (ml); Pg = mass of ovaries (g); Pe = ovarian sample weight (g).

Statistical treatment

Statistical analyses were performed using the null hypothesis test of observed differences between estimated variables (proportion of males and females), and the chi-square test.

The ANOVA statistical analysis was performed under R 4.0.4 using the R Commander package. It was used to analyze the results of GSI, HSI and the condition factor (K) data.

RESULTS

Sex ratio

Of a total of 2210 specimens, 1162 were males (53%) and 1048 females (47%). The overall sex ratio (SR) determined in the two cycles equaled 0.90 (X2=5.9, P≤0.001). The males outnumbered the females and the sex ratio was consistently in favor of males during the first year (2018) of sampling, while the females outnumbered the males during the January–December 2019 period (Tab. 2).

Sex distribution by size class

The distribution of the sexes (male and female) according to length was determined by grouping the specimens into 1 cm interval size classes, ranging from 11 to 31 cm. The sex ratio with regard to fish size showed that females dominated in the 19–31 cm size range, with males being well represented in small size classes (11–13 cm) and dominating the 14–17 cm size classes, while in size classes 18–20 cm the distribution of specimens was balanced between females and males (Fig. 2).

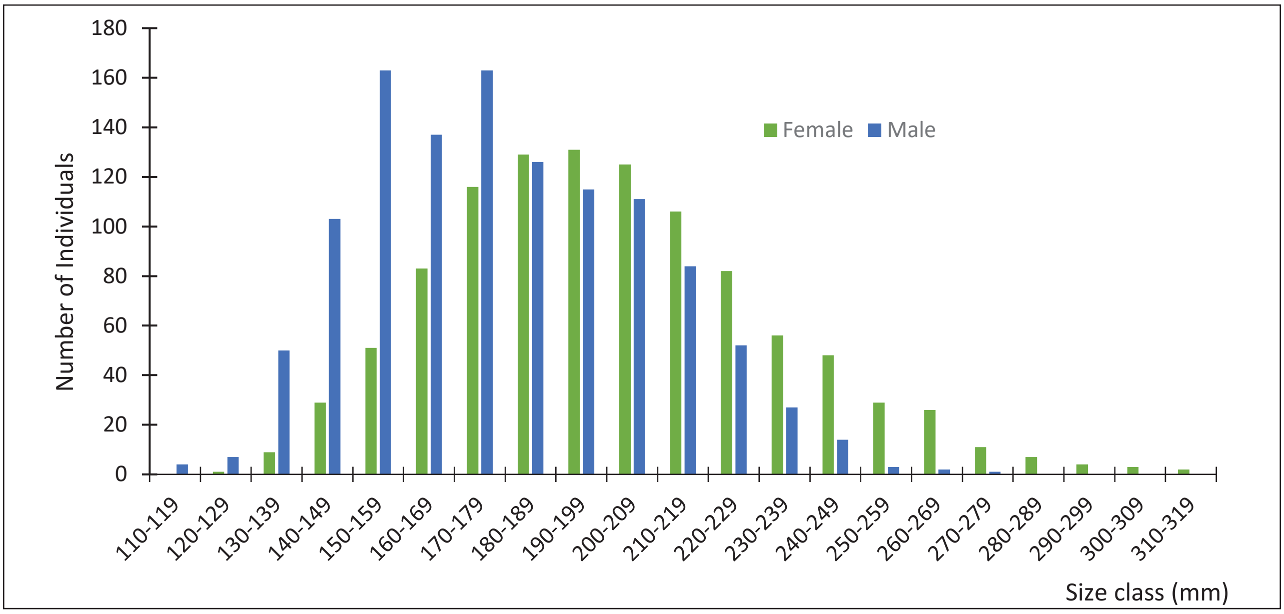


Fig. 2: Sex distribution by size class (male and female) of* T. luscus *in the Moroccan Central Atlantic coast over the period between January 2018 and December 2019 (size in mm).
Sl. 2: Porazdelitev spola po velikostnih razredih (samci in samice) vrste* T. luscus *na maroški obali srednjega Atlantika v obdobju med januarjem 2018 in decembrom 2019 (velikost v mm).

Seasonal sex ratio

The sex ratio is inconstant over the life of most fish species. The femininity and masculinity frequency changes of *T. luscus* were determined monthly from January 2018 to December 2019 (Fig. 3). The sex ratio showed irregular frequencies of females in the catches and their predominance during breeding periods. The values fluctuated between 20.22% in September 2018 and 48.44% in February 2019, with peaks of 70.58% in December 2018 and 90.90% in November 2019. The chi-square test showed that the difference between the frequencies of males and females was very significant, however, males showed high proportions only in 2018 (Fig. 3). The male sex ratio fluctuated between 29.41% in December 2018, 79.77% in September 2018, 9.09% in November 2019, and 51.55% in February 2019 (Fig. 3).

Average sizes of males and females of *T. luscus*

During the sampling period (2018–2019), the average length in females was 199.8 mm (standard error=32.04587, N=1048) and 175.5 mm in males (standard error=27.63253, N=1162). A statistical comparison (using R software) yielded an average length value of t= 2.2e-16 for both sexes, less than the theoretical value of 1.96 given in the Student's *t*-test tables. The results confirm that females were consistently more numerous than males.

Breeding season

a. Sexual maturity by sex

A macroscopic examination of the testes and ovaries showed the monthly development of sexual maturity in stages as presented below, with seasonal variation in the percentages indicating that males and females at all different stages of sexual maturity occur throughout the year but in varying ratios (Fig. 4). Pouting in post-lay or emission (stage V) were poorly represented in our samples. Early maturation (stage III) and mature (stage IV) females were encountered throughout each year but it was in the November to April period that the percentages of these two stages were the highest. The lowest percentages of mature individuals were observed in the May to July period. During this season, most individuals finished breeding and entered a period of sexual rest.

b. Monthly evolution of the gonado-somatic index

The bimonthly variations of the gonado-somatic index (GSI) were similar in both sexes during 2018–2019 and showed an ascending phase from September–October (2018) to April–May (2019) when the maximum values were reached, 3.50 for females and 3.30 for males; the descending phases occurred during January–June 2018 and March–May 2019 (Fig. 5). In both years the index dropped to minimum values for both sexes (0.57

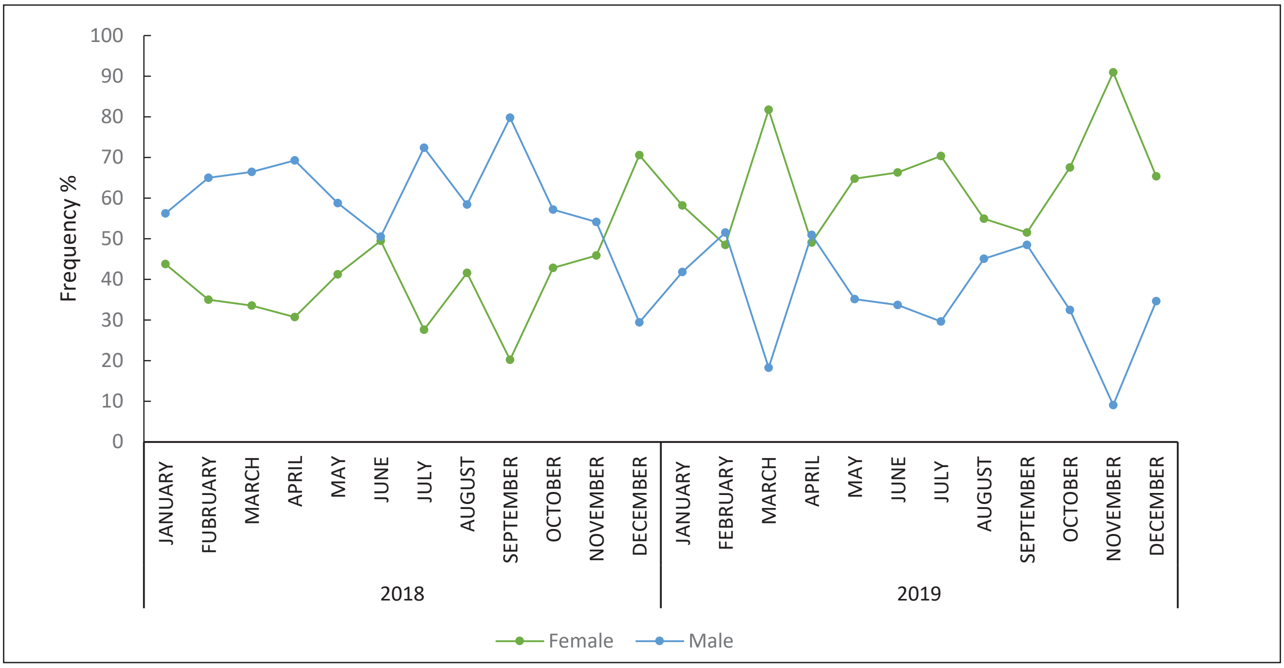


Fig. 3: Monthly and annual distributions of females and males of* T. luscus *in Moroccan Central Atlantic waters.
Sl. 3: Mesečne in letne porazdelitve samic in samcev vrste* T. luscus *v maroških vodah srednjega Atlantika.

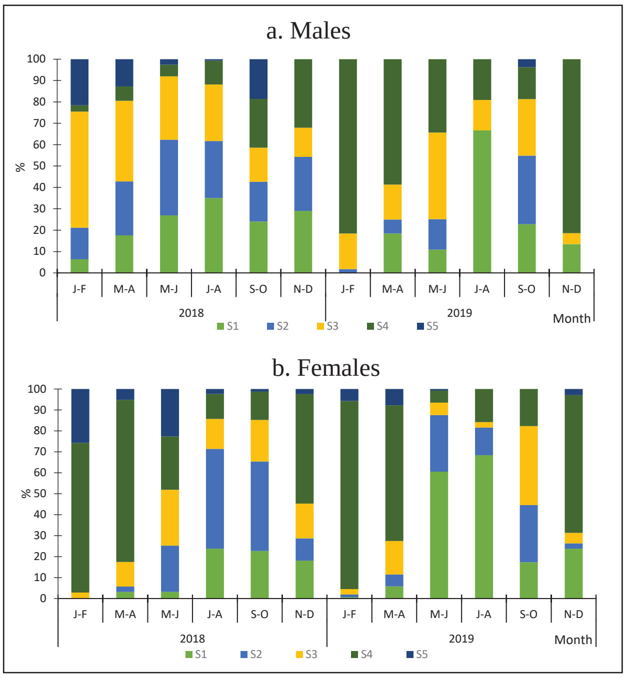


Fig. 4: Bimonthly percentages of stages of sexual maturity on a macroscopic scale in (a) males and (b) females of* T. luscus *in the Moroccan Central Atlantic coastal area over the period January 2018 – December 2019.
Sl. 4: Dvomesečni deleži faz spolne zrelosti na makroskopskem nivoju pri (a) samcih in (b) samicah vrste* T. luscus *na maroškem obalnem območju srednjega Atlantika v obdobju januar 2018 – december 2019.

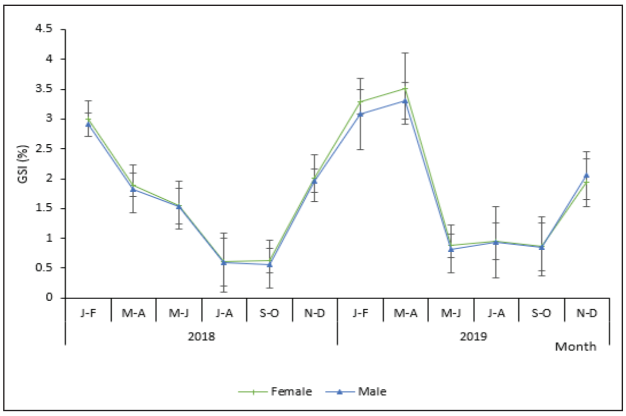


Fig. 5: Annual cycle of the gonadosomatic index GSI (mean ± SD) in males and females of* T. luscus*, in the Moroccan Central Atlantic coastal area over the January 2018 – December 2019 period.
Sl. 5: Letna dinamika gonadosomatskega indeksa GSI (povprečje ± SD) pri samcih in samicah vrste* T. luscus *na maroškem obalnem območju srednjega Atlantika v obdobju januar 2018 – december 2019.

in females and 0.56 in males) during July–October and June–September, respectively. The most stable periods were those of vitellogenesis and laying during March–April. Despite overall similarities of the male and female GSI curves, the ANOVA test indicated a small significant difference between the two sexes (p =0.05).

c. Monthly maturity stages in females on a microscopic scale

Seasonal variation in percentages of sexual maturity stages showed that females at different stages of sexual maturity can be found throughout the year (Fig. 6). As on a macroscopic scale, stage V individuals were poorly represented in our samples. Mature or laying individuals (stage IVa and IVb) were encountered throughout the year, but it was in the November 2018 to April 2019 period (late autumn, winter and spring) that their percentages were the highest. The lowest percentages of mature or laying individuals were observed from May to July, which corresponds to observations on a macroscopic scale. Towards the end of that season most individuals finished breeding and entered a period of sexual rest.

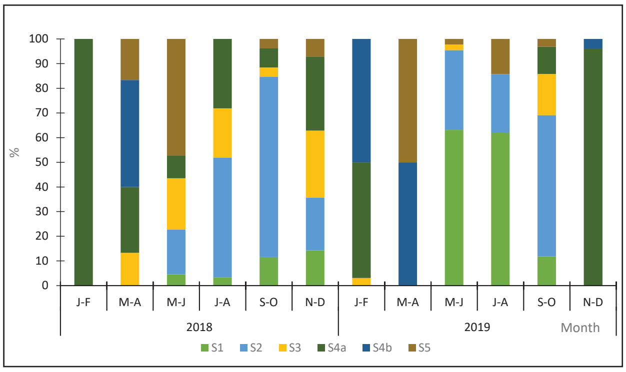


Fig. 6: Bimonthly percentages of stages of sexual maturity on a microscopic scale in females of* T. luscus*, in the Central Atlantic coast of Morocco over the January 2018 – December 2019 period.
Sl. 6: Dvomesečni deleži faz spolne zrelosti na mikroskopskem nivoju pri samicah vrste* T. luscus *na osrednji atlantski obali Maroka v obdobju januar 2018 – december 2019.

Hepatosomatic index (HSI)

Values of HSI increased sharply during September–October and November–December 2018, reaching a maximum value of 4.16 in females and 3.60 in males; a similar but somewhat smaller increase occurred in 2019 (Fig. 7). Curves of the monthly development of HSI followed the same trend in both sexes but the values showed a significant difference (p =0.05).

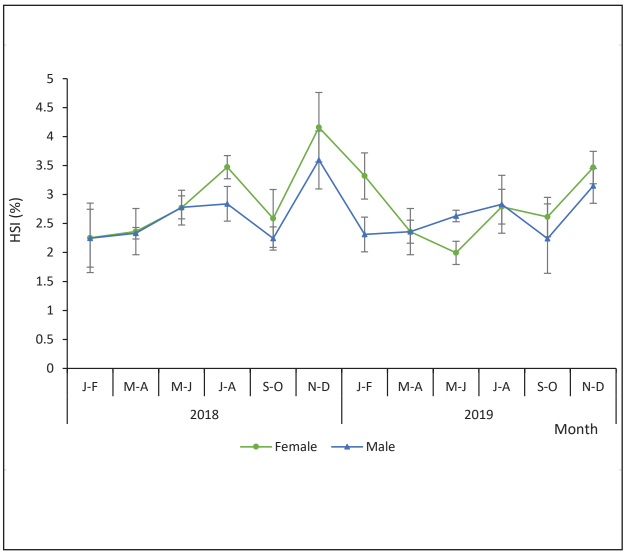


Fig. 7: Annual cycle of the hepatosomatic index HSI (mean ± SD) in males and females of *T. luscus* **in the Moroccan Central Atlantic coastal area over the January 2018 – December 2019 period.**
Sl. 7: Letna dinamika hepatosomatskega indeksa HIS (povprečje ± SD) pri samcih in samicah vrste *T. luscus* **na maroškem obalnem območju srednjega Atlantika v obdobju januar 2018 – december 2019.**

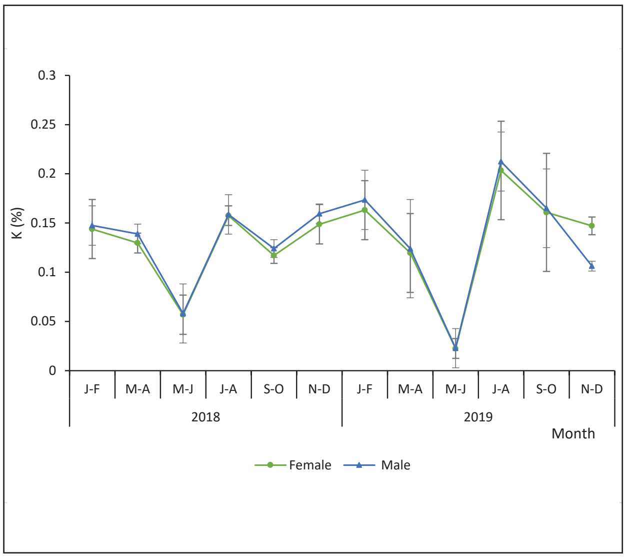


Fig. 8: Annual cycle of the condition index K (mean ± SD) in males and females of *T. luscus* **in the central Atlantic Moroccan Coastal area, over the period January 2018 – December 2019.**
Sl. 8: Letna dinamika indeksa kondicije K (povprečje ± SD) pri samcih in samicah vrste *T. luscus* **na maroškem obalnem območju srednjega Atlantika v obdobju januar 2018 – december 2019.**

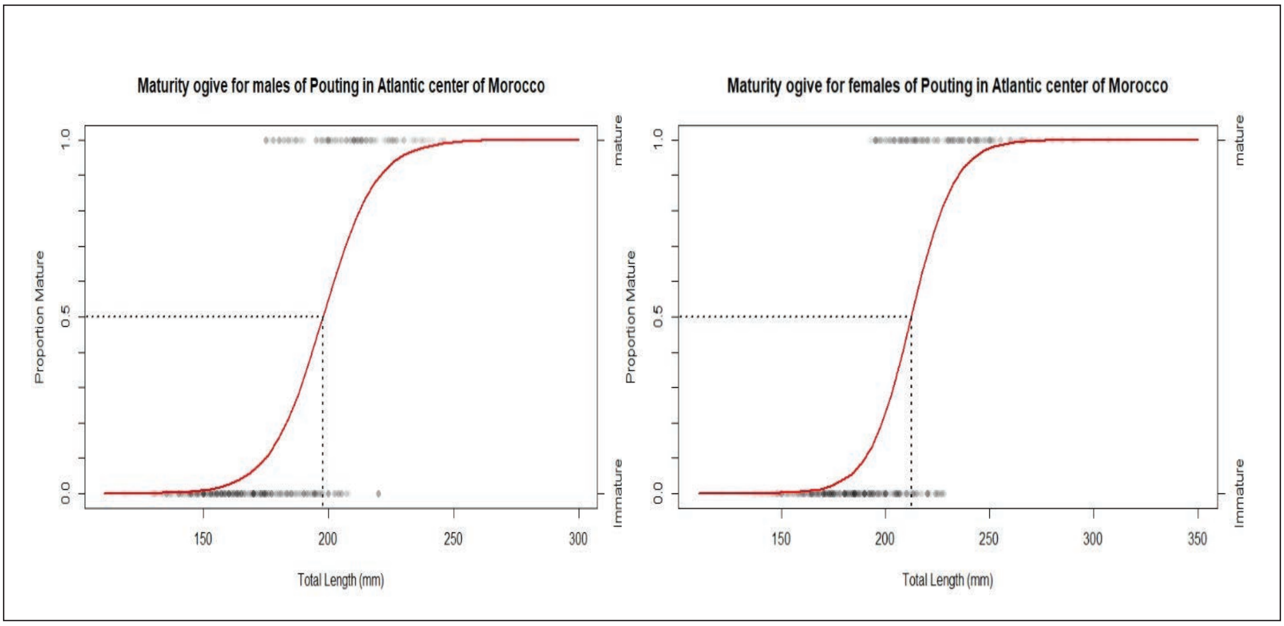
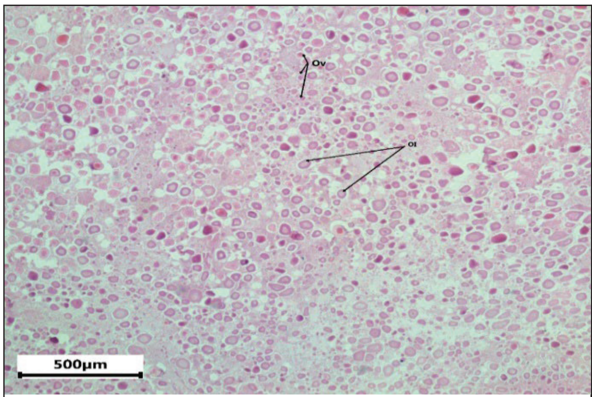
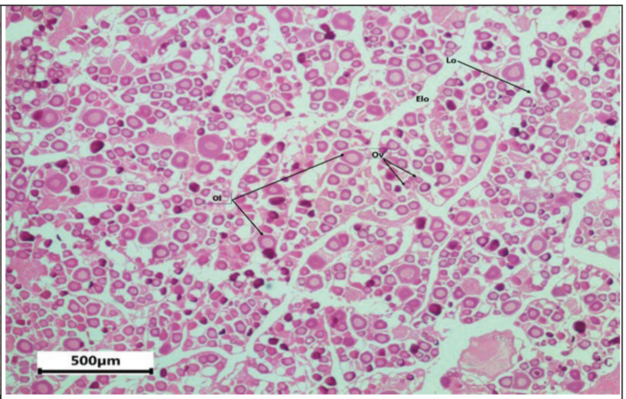


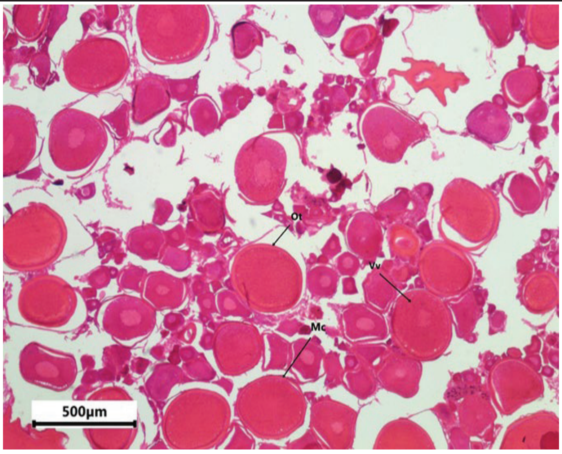
Fig. 9: Maturity ogive and length at first maturity (L50) in (a) males and (b) females of *T. luscus* **from the Moroccan Central Atlantic coastal area over the period January 2018 – December 2019.**
Sl. 9: Zrelostna ogiva in dolžina pri spolni zrelosti (L50) pri (a) samcih in (b) samicah vrste *T. luscus* **na maroškem obalnem območju srednjega Atlantika v obdobju januar 2018 – december 2019.**



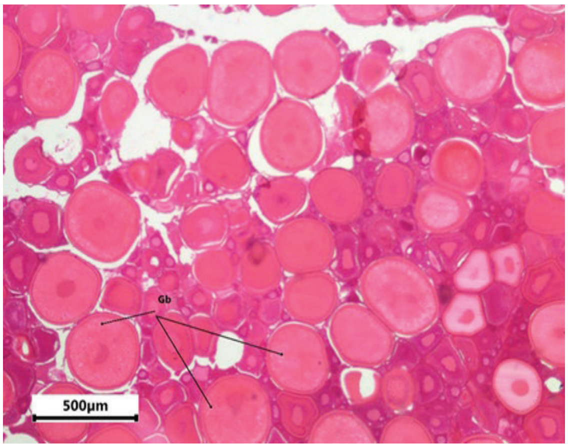
Stage 1. Immature: Growth oocyte (Ov), cytoplasm (C), primary oocyte phases I (OI).



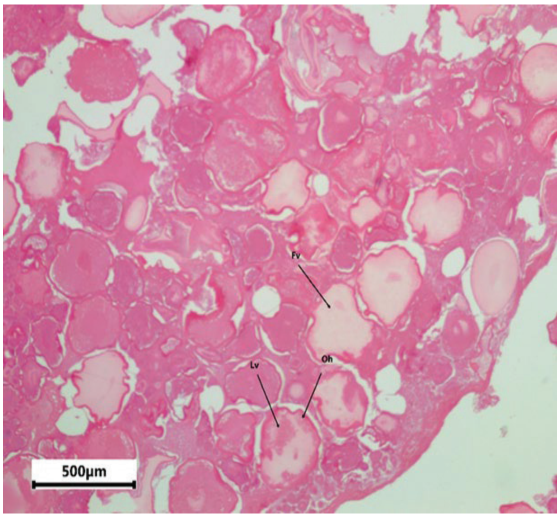
Stage 2. Start of development
Oocyte II, nucleus (N), cytoplasm (C), cortical alveoli (Co), ovarian-light (Lo), inter-lamellar space (Elo).



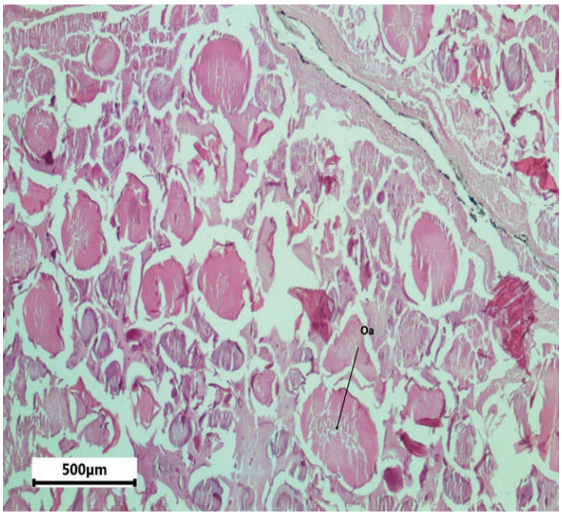
Stage 3. Vittelogenesis: Oocyte phase III (OII), Cytoplasm Membrane (Mc), yolk vesicles (Vv).



Stage 4a. Pre-spawning
Globules (Gb).



Stage 4b. Spawning
Hydrated-ovocytes (Oh), vitellus liquefaction (Lv), Empty follicles (Fol).



Stage 5. Post-spawning and Recovery
Ateritic-oocyte (Oa).

Fig. 10: Microscopic sexual maturity stages in oocytes of the *T. luscus* ***from the Moroccan Central Atlantic coast.***
Sl. 10: Faze razvoja jajčnih celic na mikroskopskem nivoju pri vrsti *T. luscus* ***iz maroške osrednje atlantske obale.***

Condition index (K)

Condition index K values ranged from 0.02 to 0.21 in females and from 0.01 to 0.22 in males (Fig. 8). A good condition phase occurred in winter, peaking during January–February 2019 at 0.17 in females and 0.18) in males, and in summer 2019, with a marked peak in July–August at 0.20 in females and 0.21 in males. (Fig. 8). The statistical analysis showed a significant difference between the two sexes in condition index values (p =0.05).

Maturity ogive and length at first maturity (L50)

The average sizes (lengths) corresponding to L50 for the study period (January 2018 to December 2019) were 19.8 cm and 21.5 cm for males and females, respectively (Fig. 9). They varied marginally according to sex. The curves indicate that males reached sexual maturity at a smaller size than females.

Gonadal kinetics and dynamics study

Microscopic anatomy of the ovary

The cytological follow-up of ovarian dynamics in the female pouting through its sexual cycle showed that the ovary contained oogonia scattered between follicular cells, oocytes in pre-vitellogenesis, and oocytes in various stages of vitellogenesis. (Fig. 10). The ovary initially consists of a set of ovarian follicles and connective tissue (Fig. 10, stage I). Oocyte growth is divided into two phases: the pre-vitellogenic phase, which marks the establishment of the metabolic machinery essential for the development of the germ cells, and the phase of vitellogenesis, which serves the accumulation of gametes (at different stages of maturation), surrounded by a theca and separated by connective tissue. Observations of ovary cross-sections correspond to the five stages selected by macroscopy (cf. Table 1) according to the descriptions in Figure 10.

Oocyte population size structure and laying strategy

The histological study was supplemented by the determination of size and number of oocytes in the ovaries of females selected as representing the different phases of the cycle (Fig. 11).

Each ovarian histological type corresponded to one or more distributions of oocyte diameters observed in the females selected as representative of the population. The succession of distributions over time traced the development of vitellogenic oocyte batches to maturity, thus defining the spawning strategy of the species. The spawning or egg laying strategy constitutes the basis for assessing fish fecundity (Dominguez *et al.*, 2008).

In immature females, the distribution of oocyte diameters was unimodal: a single batch of oocytes with a mode of 100 µm was distinguished. It was mainly formed by stage I oocytes and some stage II oocytes with diameters between 150 and 200 µm (Fig. 11).

At the beginning of development, the distributions of oocyte diameters were formed mainly of stage II oocytes and a few stage I oocytes of 100 µm. In the vitellogenic stage (stage III), oocyte diameters ranged from 250 to 400 µm.

Distributions of female fish in vitellogenesis were heterogeneous – bimodal, tri-modal or multimodal. The oocytes were divided into a number of modes corresponding to successive oocyte emissions. Maturation of the oocytes therefore occurred in successive waves. As the first group of oocytes matured, a second group took its place, and so on. A widening of the histogram base could be observed as vitellogenesis progressed and the distribution of oocytes developed (Fig. 11), with the largest oocytes attaining a diameter of 700 µm.

All distributions had a first batch of pre-spawned oocytes, with the highest number exhibiting a modal diameter of 300 µm. They differed by the emergence of one or more modes in the vitellogenic oocyte population present. The plurimodal distributions consisted of three batches of vitellogenic oocytes. The first two modes were at 300 and 400 µm, the third at 500 µm. Batches observed in polymodal distributions likely presented bimodal or tri-modal distribution patterns, but overlap prevented their detection.

Pre-vitellogenesis oocytes were present throughout the vitellogenesis stage in the ovary.

The distribution of oocytes according to size indicated continuity between pre-vitellogenic and vitellogenic oocytes. The transition of oocytes to vitellogenesis was continuous during the maturation phase.

In spawning females, the size distributions of oocytes are from November to February (Fig. 6). The last batch of oocytes in tertiary vitellogenesis was converted, by successive hydration, into batches of oocytes to be emitted in different waves of laying.

In the population of opaque vitellogenic oocytes, lighter and larger oocytes corresponded to oocytes in the process of hydration, exhibiting diameters of 400 to 500 µm (450 µm mode), or hyaline oocytes with diameters of 600–700 µm.

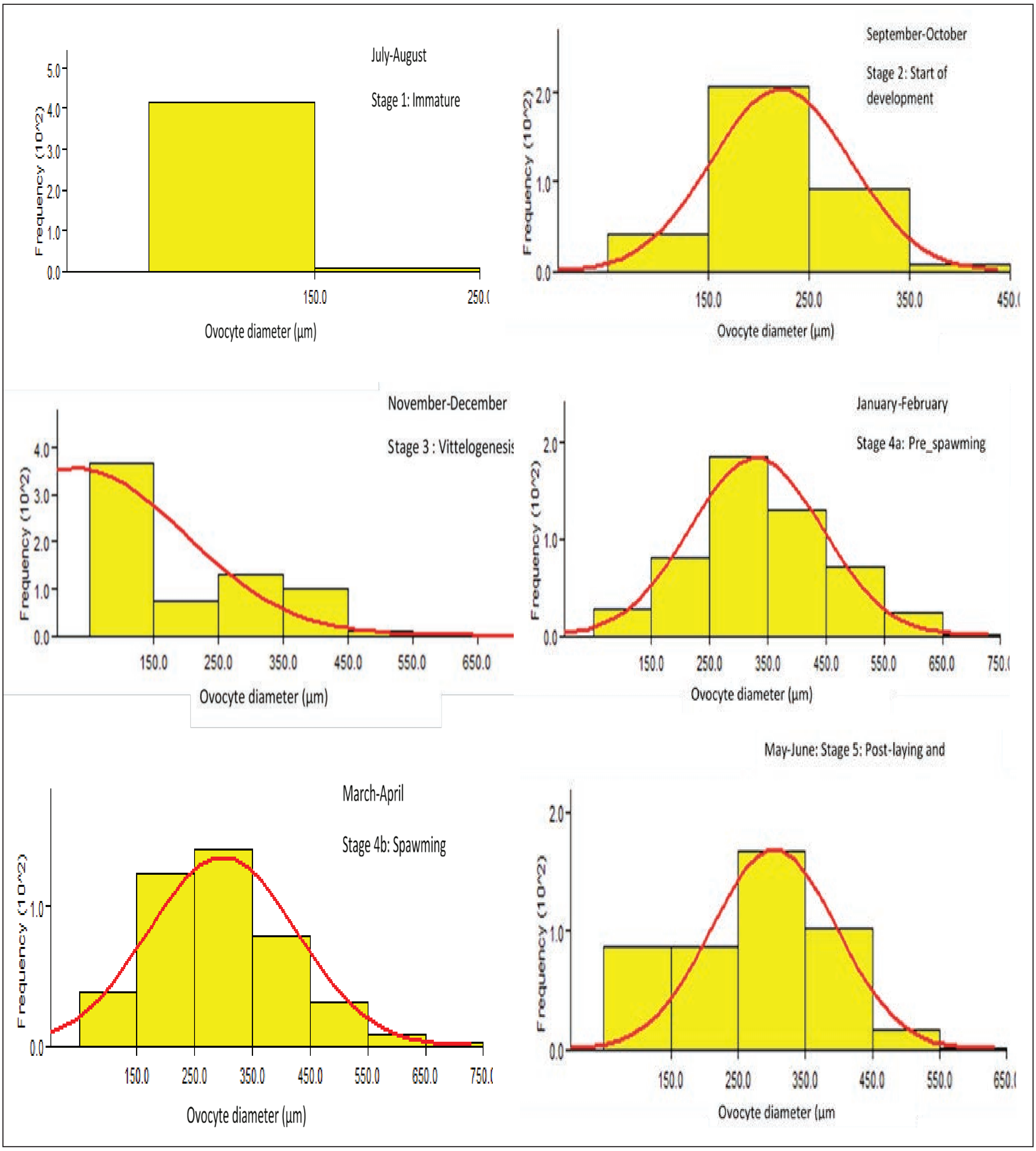


Fig. 11: Size structure of the oocytes in *T. luscus*.
Sl. 11: Velikostna struktura jajčnih celic pri vrsti *T. luscus*.

Recruitment of egg cells into vitellogenesis continued throughout the spawning phase.

Oocytes filled with vitellin reserves occupied most of the ovary and stood alongside smaller oocytes at the beginning and during maturation (Fig. 10).

Distributions of post-spawning females can be tri-modal. The only visible batch in this study consisted of pre-vitellogenic oocytes and vitellogenic, i.e., stage III and IV oocytes. The frequency of vitellogenic oocytes was lower than that found

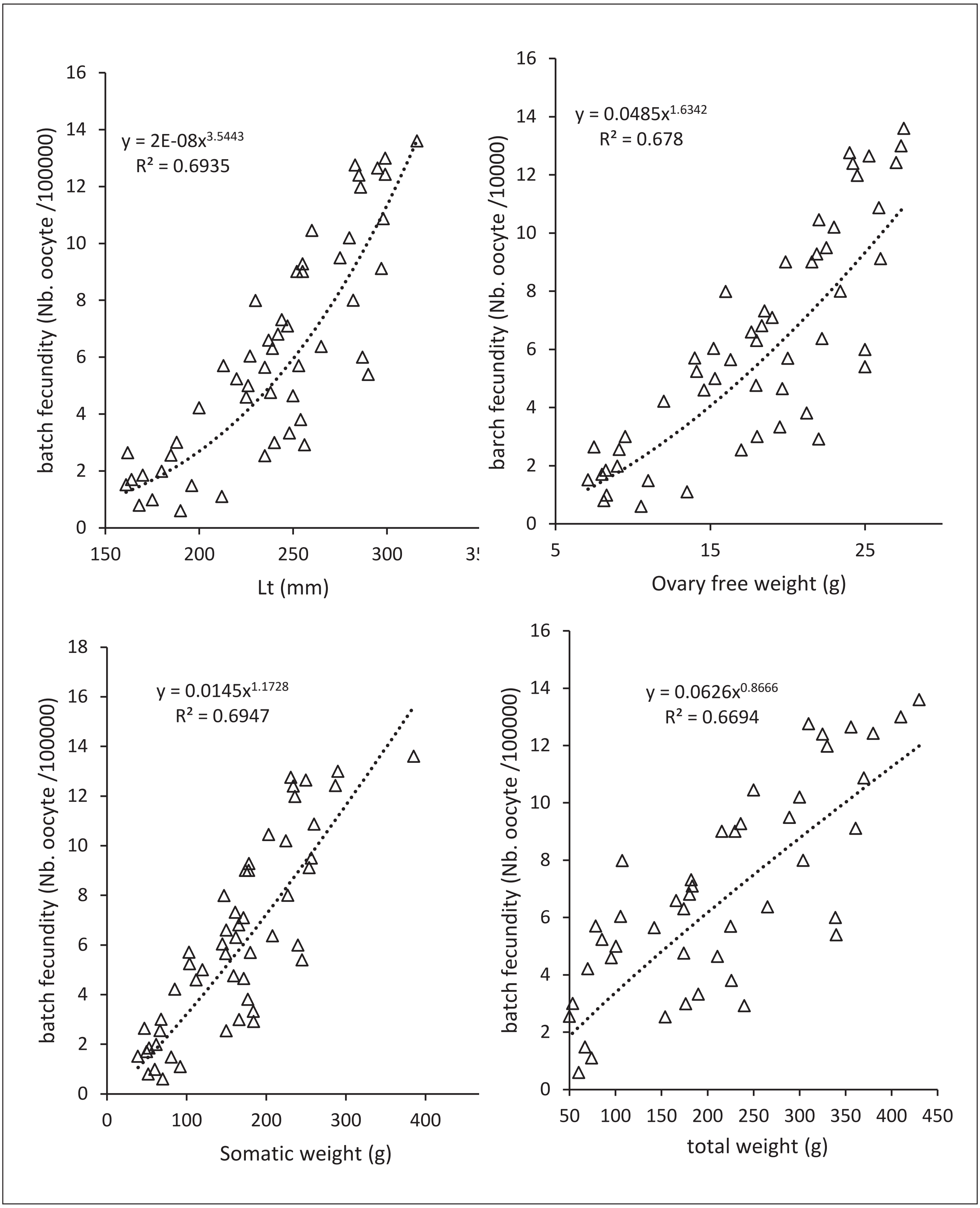


Fig. 12: Relationships between batch fecundity and total length (upper), ovary free weight (lower), somatic weight, and total weight of the* T. luscus *from the Moroccan Central Atlantic coast.
Sl. 12: Razmerja med drstitveno plodnostjo in skupno dolžino (zgornja), prosto težo jajčnikov (spodnja), somatsko težo in celotno težo primerkov vrste* T. luscus *z maroške obale srednjega Atlantika.

in laying females, but their presence indicates that oocytes progressed to vitellogenesis continually throughout the spawning period (Fig. 11).

Batch and relative fecundity

Batch fecundity (number of viable eggs usually released by a serial spawner during a pulse of spawning) is between 15,146 and 136,031 eggs with an average value of 61,848 eggs per pulse. The relative fecundity oscillated between 15,146 (Lt = 161 mm, Pe = 38.9 g) and 136,031 (Lt = 316 mm, Pe = 385.1 g) with an average of 325.37 and 142.48 eggs/g, respectively. The relationships observed between fecundity and the different biological parameters are shown graphically (Fig. 12), the highest correlation being between somatic weight and batch fecundity:

- Total length; $Fa = 2*10^{-8}Lt^{3.443}$, r = 0.693 (Fig. 12);
- Ovary free weight; $Fa = 0.048\ Pg^{1.634}$, r = 0.678 (Fig. 12);
- Somatic weight; $Fa = 0.0145\ Pe^{1.728}$, r = 0.964 (Fig. 12);
- Total weight; $Fa = 0.0625\ Pt^{0.866}$, r = 0.699 (Fig. 12).

DISCUSSION

Several indices are used to determine and visualize the breeding periods of many demersal fish species. Their selection is based on the quasi-simultaneity of the maximum index values associated with the spawning periods. At least two indices are needed to assess the reproduction and fecundity in *Trisopterus luscus*.

Determination of the maximum egg-laying period of the pouting in European waters of the North-East Atlantic is based on the abundance of eggs and larvae, ovarian histology, and development of the gonado-somatic index (GSI) (Lahaye, 1972; Dominguez *et al*., 2008).

To investigate sexual maturity changes and identify the spawning periods in the Moroccan population, this study used a variety of variables and indices, including the GSI (gonad development phases) and HSO (hepatosomatic condition) indices, the condition factor (K), gonad histology, size at first sexual maturity (L50), and the sex ratio. Monthly sampling (from January 2018 to December 2019) clearly showed two cycles in the overall sex ratio and a slight predominance of males in the catches. This dominance can be explained by either relative mortality of females during reproduction, differences in growth in favor of males or regrouping to reproduce during the intense laying season (Amenzoui *et al.*, 2004–2005).

The sex ratio in terms of size indicated a dominance of females in larger size classes and males in the small ones. This dominance of older females could, according to several authors, have several explanations, including greater availability or capturability of males, a higher natural mortality of males, sexual inversion, or more simply differential growth with different longevity of the two sexes favoring females (Amenzoui *et al.*, 2004–2005). The gonad maturation index (GSI) increase for this species coincided with gametogenesis and its decrease indicated active egg laying (cf. Lahaye, 1972). The GSI values of females were higher than those of males due to the large size of the ovaries. Seasonal development of the GSI showed the periods of sexual activity for the Moroccan pouting which, combined with data on sexual maturity stages, indicated that this population can reproduce throughout the year, with a maximum peak registered between January and February 2018 and between March and April 2019. We also observed the presence of some spawning females throughout the year. The results did show some variation between 2018 and 2019 in spawning time and coincidence with findings of other authors covering different areas of the Atlantic Ocean where breeding seasons seem to vary depending on the region. Indeed, for the pouting this extends from February to June in the English Channel, from March to July in the French part of the North Sea (Desmarchelier, 1985), and from January to April in the south of the Bay of Douarnenez, France (Gherbi-Barre, 1983). A shift in the laying period further into spring thus appears to gradually occur from the south to the north of France, with a delay of about one month in the beginning of spawning between one zone and another (Desmarchelier, 1985). In north-west Spanish waters female pouting reaches higher maturity and exhibits asynchronous oocyte development (Alonso-Fernández, 2008), which corresponds well to the results of our study, but further monitoring of Moroccan stock is needed to draw firm comparative conclusions about the timing of spawning sequences.

In the Moroccan sample no females at rest (stage V) were observed from June to August and in the fall, and few at this stage were encountered in winter and spring. This would lead us to conclude that egg spawning in *T. luscus* in the studied area takes place all year round with varying intensities depending on the season. However, the morphological development of the gonads is an imprecise indicator of the state of reproduction as it does not determine the degree of ovarian mortality. Therefore, microscopic analysis was essential to determine the timing of gamete maturation stages within the limits of the bimonthly sampling program.

On a microscopic scale, histological examination of female *T. luscus* gonads indicates somewhat asynchronous ovary maturation for this species (Wallace and Selman, 1981; Murua and Saborido-Rey, 2003). The ovary contains oocytes at all stages of development throughout the year and the simultaneous presence of walled oocytes and post-ovulatory follicles in female ovaries indicates that *T. luscus* is a partial breeder. This was also observed for the same species in Galician coastal waters (Alonso-Fernández, 2008). It should also be noted that the spawning season of pouting is long and some females are in a state of spawning throughout the year. However, most females from our sample began spawning in the first part of the year, peaking between February and April, which corresponds to results reported by Labarta & Ferreiro (1982) and Merayo (1996a).

Monthly monitoring of the hepatosomatic index (HSI) showed a similar development pattern to that of the GSI with maximum values being reached at the same time, indicating that the liver does not intervene strongly in the transfer of lipid reserves necessary for vitellogenesis. The HSI in males showed similar variations as in females, and maturation of the male gonads therefore also required much energy with the liver losing its reserves in November, when the testes were mature. Weight was regained and was highest in December when testes were poorly developed. It was also noted that the final maturation of oocytes seemed to be associated with a rapid use of liver reserves. This caused lowering of the HSI during the final phase of vitellogenesis (February–March). During periods of sexual rest, the liver accumulates reserves that represent about 4.5% of the body weight (Desmarchelier, 1985).

In *T. luscus*, some lipid storage occurs in muscles within or between muscle fibers according to Desmarchelier (1985). The monthly change in the condition coefficient (K) in this study followed both the GSI and his indices indicating that muscle fat reserves were used in the female development at the end of vitellogenesis. The energy developed during the spawning and the lack of food clearly contributed to the weight loss of females at this time. In June, the pouting begins to recharge and takes on a more rounded shape. This period corresponds to more favorable growth in the summer and fish are in best condition in October–November before losing weight again in winter. In males, the K factor is correlated with the GSI showing an inverse trend with the GSI; however, reproductive performance in both males and females ultimately depends on the prevailing environmental conditions. The K weight index also serves as an indicator characterizing the pouting as a "fatty" as opposed to "lean" fish, such as the horse mackerel. Our observations on the development of these indices generally confirm those of studies carried out in the English Channel (Desmarchelier, 1986).

This interannual variability is principally caused by prevailing environmental conditions, including date of initiation of laying (early or late laying depending on the year), the corresponding annual recruitment and food availability (Abad *et al.*, 1993). The L50 can also vary according to sex and size at first sexual maturity (L50); in the Moroccan pouting it was 21.5 cm in females and 19.8 cm in males, whereas in Galicia (Spain) the L50 in females was estimated at 18.2 cm (Labarta *et al.*, 1982) and 22 cm in males (Alonso-Fernández *et al.*, 2008). The variations in size at first maturity may also reflect the different strategies developed by fish in different environments to better adapt to the environmental conditions.

The development of mean oocyte diameter showed a small but important decrease over the spawning season, possibly suggesting recruitment of new oocytes to the stock of developing oocytes throughout the spawning season, a characteristic of species with indeterminate fecundity (Hunter *et al.*, 1989). The observed decrease may also have been a consequence of asynchronous development of the oocytes. However, when mean oocyte diameter was analyzed in the successive ovary developmental stages (instead of over the season), it showed a slight increase suggesting no *de novo* vitellogenesis after the onset of ripening, i.e., determinate fecundity (Alonso-Fernández *et al.,* 2008). Consequently, the issue of determinate or indeterminate fecundity in the Moroccan *T. luscus* stock remains inconclusive, although the latter is considered most probable.

The relative batch fecundity of pouting in this study ranged from 5 to 67 eggs g^{-1} (fish weight range: 108–366 g). This contrasts with other indeterminate spawning species, which produce larger batches, such as *Merluccius merluccius, M. capensis* and *M. paradoxus*, with 123, 160, and 306 eggs g^{-1} of relative batch fecundity, respectively, or with clupeids, e.g., *Sardina pilchardus* with close to 350 eggs g^{-1} (Ganias *et al.*, 2004; Murua *et al.*, 2006). The ratio between the number of developing oocytes and batch fecundity displayed an average value of 20. Therefore, assuming a spawning season of 4–5 months, the pouting could produce a batch every 6–7 days. This means that if the pouting is a determinate spawner, a female will spawn an average of 20 batches during the spawning season: a figure very close to that for other determinate fecundity species (Kjesbu 1989; Kjesbu *et al.*, 1996). Fertility will always be af-

fected by the changing environmental conditions including predation and exploitation (Mura *et al.*, 2003; Ganias, 2009), thus challenging predictive modeling of stock sustainability.

CONCLUSIONS

This is the first investigation of the reproductive biology of the pouting *Trisopterus luscus* in the Moroccan Central Atlantic fishery area. Random bimonthly sampling of the Moroccan pouting population showed a dominance of the males during two annual cycles (2018–2019) and indicated that reproduction probably took place during most of the year, but maximum spawning occurred during the January-February 2018 and January–March 2019 periods. The 50% level of population maturity (L50) at a total length of 19.8 cm in males and 21.5 cm in females compares fairly closely with that of more northern stocks. Nevertheless, further sampling and study are required in order to confirm the frequency and differentiation of sex ratios according to season and other aspects of the reproductive biology of *T. luscus* in Moroccan waters.

REPRODUKTIVNA BIOLOGIJA FRANCOSKEGA MOLIČA (*TRISOPTERUS LUSCUS)* IZ ATLANTSKE OBALE MAROKA

Nassima EL OMRANI
Laboratory of Aquatic Systems: Marine and Continental Ecosystems, Faculty of Sciences, Ibn Zohr University, Agadir, Morocco
e-mail: naelomrani007@gmail.com

Hammou EL HABOUZ
Laboratory of Fisheries, National Institute of Fishery Research (INRH), Agadir, Morocco

Abdellah BOUHAIMI & Jaouad ABOU OUALID
Laboratory of Aquatic Systems: Marine and Continental Ecosystems, Faculty of Sciences, Ibn Zohr University, Agadir, Morocco

Abdellatif MOUKRIM
Faculty of Sciences, Abdelmalek Essaadi University, Tetaouan, Mococco

Jamila GOUZOULI
Faculty of Sciences, Ait Meloul, Agadir, Morocco

Mohammed RAMDANI
Department of Zoology & Ecology, Scientific Institute, Mohammed V University of Rabat, Morocco

Roger FLOWER
Department of Geography, UCL - University College London, London, WC1E 6BT, UK

Abdelbasset BEN-BANI
Laboratory of Fisheries, National Institute of Fishery Research (INRH), Agadir, Morocco

POVZETEK

*Avtorji poročajo o izsledkih dvoletne raziskave (januar 2018 – december 2019) o reproduktivni biologiji francoskega moliča (*Trisopterus luscus*) na maroškem obalnem območju, o kateri sicer ni veliko znanega. Pregledali so 2210 vzorčenih primerkov, od katerih je bilo 1162 samcev (52,57%) in 1048 samic (47,42%), pri čemer so bili samci statistično značilno (hi kvadrat test) bolj številčni. Mesečni monitoring gonadosomatskega indeksa (GSI) in makroskopski ter mikroskopski pregled gonad so pokazali, da so se francoski moliči aktivno razmnoževali skozi vse leto z viškoma v januarju–februarju 2018 in marcu–aprilu 2019. V obeh primerih je bil tudi višek indeksa kondicije (K). Nadalje avtorji razpravljajo o spremembah razmnoževalnih značilnosti francoskega moliča v povezavi z dolžino telesa, sezono in plodnostjo.*

Ključne besede: *Trisopterus luscus*, indeks kondicije, gonado-somatski indeks, dolžina ob spolni zrelosti, atlantska maroška obala

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GROWTH PATTERNS AND AGE STRUCTURE OF *MULLUS SURMULETUS* (MULLIDAE) FROM THE NORTHERN COAST OF TUNISIA (CENTRAL MEDITERRANEAN SEA)

Mourad CHÉRIF
Institut National des Sciences et Technologies de la Mer, port de pêche, 2025 La Goulette, Tunisia

Rimel BENMESSAOUD
Institut National Agronomique de Tunis, 43, Avenue Charles Nicolle 1082 -Tunis- Mahrajène, Tunisia

Christian CAPAPÉ
Laboratoire d'Ichtyologie, Université de Montpellier, 34095 Montpellier cedex 5, France
e-mail: christian.capape@umontpellier.fr

ABSTRACT

Age and growth of striped red mullet, Mullus surmuletus *Linnaeus, 1758 were estimated using sagittal otoliths from specimens collected off the northern coast of Tunisia between January 2005 and December 2007. In the studied sample, the males outnumbered the females (♀/♂ = 0.56). The age composition ranged from one to five years, and most specimens belonged to the one-year age group. The length-weight relationship displayed positive allometry for both sexes. The fit of the von Bertalanffy growth curve was significantly different between sexes ($p < 0.05$): $TL_\infty = 267.8$ mm, $k = 0.242$ year^{-1}, $t0 = -1.343$ years for males and $TL_\infty = 284.1$ mm, $k = 0.293$ year^{-1}, $t0 = -0.872$ years for females.*

Key words: *Mullus surmuletus*, sex ratio, growth parameters, length–weight relationship, Tunisia

MODELLI DI CRESCITA E STRUTTURA D'ETÀ DI *MULLUS SURMULETUS* (MULLIDAE) DELLA COSTA SETTENTRIONALE DELLA TUNISIA (MEDITERRANEO CENTRALE)

SINTESI

L'età e la crescita della triglia di scoglio, Mullus surmuletus *Linnaeus, 1758 sono state stimate utilizzando gli otoliti sagittali di esemplari raccolti al largo della costa settentrionale della Tunisia tra gennaio 2005 e dicembre 2007. Nel campione studiato, i maschi hanno superato le femmine (♀/♂ = 0,56). La composizione per età variava da uno a cinque anni, e la maggior parte degli esemplari apparteneva al gruppo di età di un anno. La relazione lunghezza-peso ha mostrato un'allometria positiva per entrambi i sessi. L'adattamento della curva di crescita di von Bertalanffy era significativamente diverso tra i sessi ($p < 0,05$): $TL_\infty = 267,8$ mm, $k = 0.242$ anno^{-1}, $t0 = -1.343$ anni per i maschi, e $TL_\infty = 284,1$ mm, $k = 0,293$ anno^{-1}, $t0 = -0.872$ anni per le femmine.*

Parole chiave: *Mullus surmuletus*, rapporto fra sessi, parametri di crescita, rapporto lunghezza-peso, Tunisia

INTRODUCTION

The striped red mullet *Mullus surmuletus* Linnaeus, 1758 is one of the main target species of demersal fisheries in Tunisia constituting about 3% of total catch of demersal fishes (anonymous, 2018). This species is mainly exploited by trawl fishery in southern areas and small-scale fleets in northern areas (Chérif, 2013). Several aspects of *M. surmuletus* biology have been studied, including feeding and reproduction (Chérif *et al.,* 2007a, 2008a, 2013). Only a preliminary study on the age and growth patterns of the striped red mullet in northern Tunisian areas was conducted based on a scales analysis (Gharbi, 1980). Similarly, several studies reported that otoliths are the most widely used because they have proven to be a reliable and valid method for age determination in mullid species (Mahé *et al.*, 2016; ICES, 2017. Carbonara *et al.*, 2018).

The purpose of this paper is to determine age from otolith readings and estimate the growth parameters from length-age values. Additionally, length-weight relationships of *Mullus surmuletus* are calculated for specimens from the northern coast of Tunisia. The results of the study could complement previous studies and help improve strategies and policies for a sustainable production in the area.

MATERIAL AND METHODS

The otoliths of *M. surmuletus* were monthly collected from specimens caught off the northern Tunisian coast (Fig. 1) between January 2005 and December 2007. The specimens were captured by commercial trawlers using a Tunisian shrimp trawl with a stretched-mesh size of 52 mm in the wing and 40 mm in the cod end (Chérif *et al.*, 2007b). After landing, the specimens were sorted by sex, their total length (TL) was measured to the nearest millimetre and total weight (TW) recorded to the nearest gram.

A total of 410 otoliths were used for ageing. Sagittal otoliths were removed, cleaned, and put in labelled envelopes with full information for further readings. All otoliths were placed in a concave black dish and examined using the reflected light of a binocular microscope at 10x magnification.

The length-weight relationship was described by the formula proposed by Ricker (1973): $W = aTL^b$, where (W) is the weight in grams, (TL) the total length in mm, (b) the growth exponent, and (a) is a constant. The hypothesis of isometric growth was tested using a t-test (Zar, 1999).

Growth was expressed in terms of the von Bertalanffy equation: $L_t = L_\infty (1-e^{-K(t-t_o)})$, where ($L_\infty$) is the asymptotic total length, (Lt) the total length at age (t), (K) the growth curvature parameter, and (to) the theoretical age of fish at zero total length. For weight growth, the same function was used: $W_t = W_\infty (1-e^{-k(t-t_o)})^b$, where (Wt) is the total weight, (W_∞) is the asymptotic weight, and (b) is the power constant of the length-weight relationship. The Fishparm software including the non-linear estimation method was used to estimate the growth parameters (Saila *et al.*, 1988).

RESULTS

Sample characteristics, sex ratio, and length-weight relationship (LWR)

Of the 818 examined specimens, 426 were females, 328 males, and 64 were unidentified. In the present sample females significantly outnumbered males (m/f= 0.56) 1:1 ($\chi 2=13.57$; df = 1; $P <0.05$). The TL of the striped red mullet ranged from 66 mm to 262 mm and the weight from 4.56 g to 244.73 g. The TL of females ranged from 111

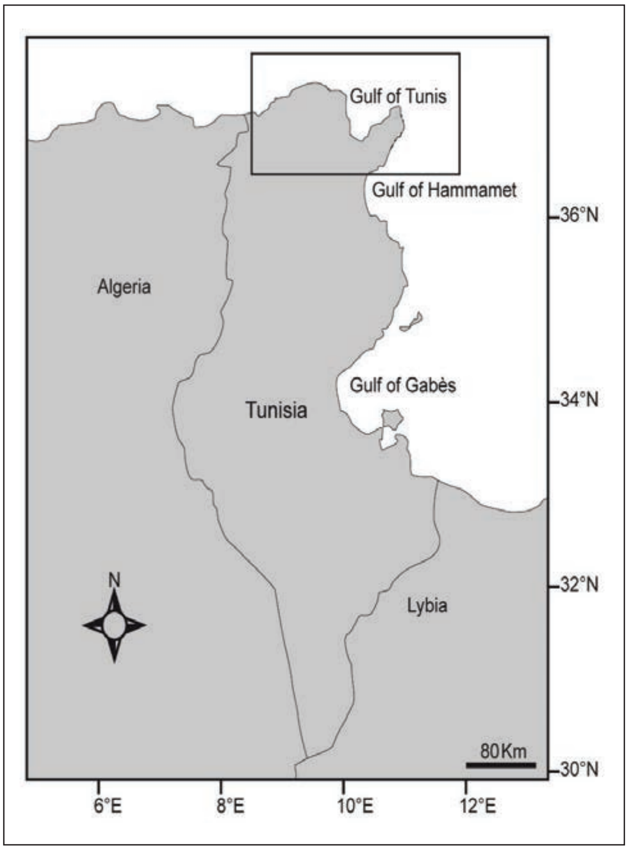


Fig. 1: Map of the Tunisian coast with a rectangle indicating the sampling area of *Mullus surmuletus.*
Sl. 1: Zemljevid tunizijske obale s pravokotnikom, ki označuje območje vzorčenja progastega bradača.

Tab. 1: Sample characteristics of* Mullus surmuletus *from the northern coast of Tunisia.
Tab. 1: Značilnosti vzorcev progastih bradačev s severne obale Tunizije.

	Length (mm)			Weight (g)		
Sex	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**
Male	105	212	145.2	9.85	123.73	34.74
Female	111	262	160.6	9.41	244.73	49.01
Unsexed	66	175	120.1	4.56	57.97	20.58

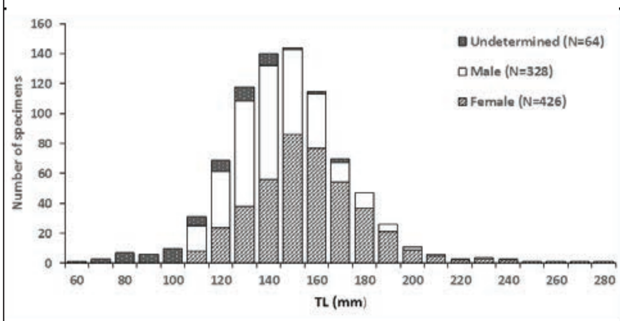


***Fig. 2: Length-frequency distribution by sex of* Mullus surmuletus.**
Sl. 2: Dolžinsko-frekvenčna porazdelitev glede na spol progastih bradačev.

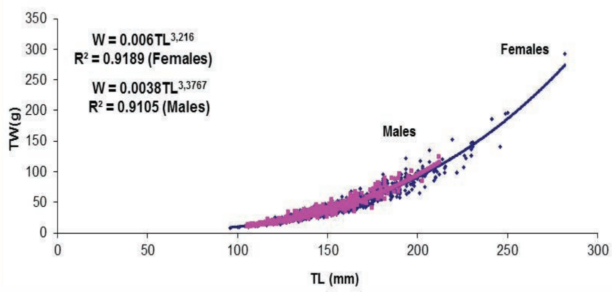


Fig. 3: Length-weight relationship of* Mullus surmuletus *(females and males).
Sl. 3: Razmerje med dolžino in težo progastih bradačev (samice in samci).

mm to 262 mm and the TL of males from 105 mm to 212 mm. The TW of females ranged from 9.41 g to 244.73 g and the TW of males from 9.85 g to 123.73 g (Tab. 1). The dominant length group was 130–160 mm, which represented 63.2% of all examined specimens (Fig. 2). Females prevailed in size classes larger than 150 mm, whereas males significantly outnumbered females in smaller size classes (c2 =9.81; df =1; P <0.05).

The length-weight relationship of *Mullus surmuletus*, as presented in Table 2 and Figure 3, indicated a positive allometry for males, females, and all specimens. The (b) coefficient was significantly different from 3 (t-test, $P < 0.05$). In addition, the (R^2) values for relationships among males, females, and all fish indicated a strong correlation between length and weight.

Age and growth

The age sample consisted of sagittal otoliths from 218 females, 104 males, and 88 fish of unidentified sex. Age estimates ranged from 1 to 5 years for males, females, and all specimens. Most of the fish, i.e., 90% of the total sample, were between 1 and 3 years old (Fig. 4). Specimens older than 4 years old were poorly represented in the sample.

The von Bertalanffy relationships between age and length, derived from the assumed annual periodicity of the growth increments, were described by the growth parameters (Tab. 3; Fig 4):

$TL\infty=267.8$ mm, $k=0.242$ year^{-1}, $t_0= -1.343$ years for males;

Tab. 2: Length-weight relationship parameters of** Mullus surmuletus**.
Tab. 2: Dolžinsko-masni parametri progastih bradačev.

Equations	Sex	a	b	R^2	t-test	Allometry
$W = aTL^b$	♀	0.0061	3.216	0.9189	7.51	+
	♂	0.0038	3.3767	0.9105	9.13	+
	combined sexes	0.0036	3.3279	0.8922	11.09	+

Tab. 3: Age and growth parameters of** Mullus surmuletus **in the northern coast of Tunisia.
Tab. 3: Starostni in rastni parametri progastih bradačev na severni obali Tunizije.

	Males (N = 104)	Females (N = 218)	All individuals (N = 410)
Age (years)	TL (mm) (Average + SD)	TL (mm) (Average + SD)	TL (mm) (Average + SD)
I	115.2±1.4	120.3±0.9	117.8±0.7
II	159.4±0.3	161.4±1.1	156.7±0.6
III	182.8±0.7	192.9±1.3	182.1±0.9
IV	199.3±0.2	216.8±1.5	206.1±1.9
V	210.6±0.9	233±0.8	221.8±1.4
Growth parameters (L∞, W∞, K and t0)			
L∞ (mm)	267.8	284.1	274.6
K	0.242	0.293	0.271
to	-1.343	-0.872	-1.071
W∞ (gr)	251.8	283.5	269.96

TL∞=284.1 mm, k=0.293 year^{-1}, t_0= -0.872 years for females;

TL∞=274.6 mm, k=0.271 year^{-1}, t_0= -1.071 years for all individuals.

Females tend to grow slightly faster in length than males. The growth patterns by sex were similar up to the age of 1 year (group I), after that age, the females grew faster and attained a greater maximum length than males (Fig. 6). Significant differences were found between the growth of males and females (t-test, $P < 0.05$).

DISCUSSION

The present sample, with the females significantly outnumbering males, is in total accordance

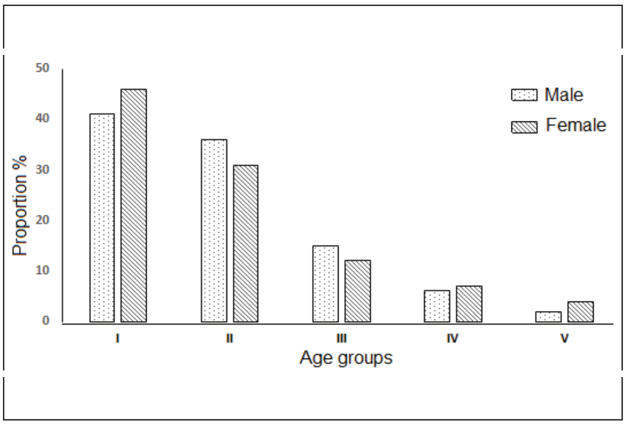


***Fig. 4: Age group proportions for females and males of** Mullus surmuletus.*
Sl. 4: Razmerja starostnih skupin za samice in samce progastih bradačev.

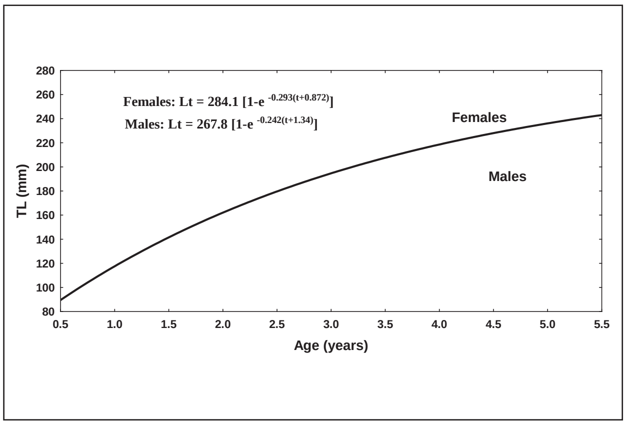


***Fig. 5: The von Bertalanffy growth curve for females and males of** Mullus surmuletus.*
Sl. 5: Von Bertalanffyjeva krivulja rasti za samice in samce progastih bradačev.

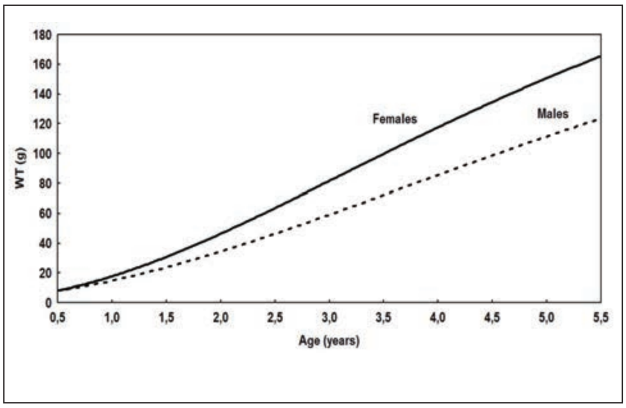


***Fig. 6: Growth patterns for females and males of** Mullus surmuletus.*
Sl. 6: Rastni parametri za samice in samce progastih bradačev.

with previous reports (Hashem, 1973; Gharbi & Ktari, 1981b; Pajuelo *et al.*, 1997; Amin *et al.*, 2016). Such pattern could be due to differences in the spatial distribution of males and females in the water column, as suggested by Lozano-Cabo (1983) and Caminias *et al.* (1990). It also appears that females are captured more frequently than males during fishing efforts because of the body shape dimorphism: females are heavier and fatter than males (N'Da *et al.*, 1993; Jabeur, 1999; Chérif *et al.*, 2007b).

The length-weight relationship of *M. surmuletus* in the northern area of Tunisia displays a positive allometric growth, showing that the species finds favourable conditions to develop and reproduce in the wild. The analyses of the LWR provided by several authors show, however, some differences in b values (Tab. 4). This variability in b values could be explained by many factors, such as food availability, environmental conditions, sampling methods, and the stage of maturity (Shepherd & Grimes 1983; Pauly, 1984; Chérif *et al.*, 2008b).

Males and females of *M. surmuletus* grew similarly in weight during the first year of life, after that age, the females grew faster and attained a greater maximum weight than males. This differential growth between sexes is attributed to differences in reproductive physiology and feeding behaviour (Ricker, 1975; Morey *et al.*, 2003; Chérif *et al.*, 2021). Mahé *et al.*, 2013 reported that the growth was important during the first year and slowed down thereafter. This reduction in the growth rate coincided with the age at first maturity, reflecting that the energy used for reproduction is no longer available for somatic growth (Pauly, 2010; Grabowska et al. 2011).

The use of whole sagittal otoliths for age determination concerning mullid species was considered to be the most suitable method and displaying the best results because the alternative pattern of translucent and opaque zones was easily distinguishable (Pajuelo *et al.*, 1997; Mahé *et al.*, 2012, 2013). Thus it was determined that the individuals sampled from the northern area of Tunisia belonged to age groups I–V. The specimens were mostly between 1 and 3 years old.

The growth rate of *M. surmuletus* recorded in this study is very similar to that reported for the same species in other areas (Tab. 4), except in the Catalonia region, where Andaloro (1981, 1982) and Sanchez *et al.* (1983) found that red

Tab. 4: Growth parameters (L∞, t0 and k) and the length-weight relationship (a and b) for *Mullus surmuletus* ***from different localities.***
Tab. 4: Rastni parametri (L∞, t0 in k) in razmerje med dolžino in težo (a in b) za progaste bradače iz različnih lokalitet.

Area	L∞ (mm)	t0	K	a	b	Reference
Marmara Sea	328.3 TL	-2.13	0.23	0.0089	3.12	Moldur (1999)
Aegean Sea	278.2 TL	-2.16	0.2	0.0084	3.12	Mukadder & Ismen (2013)
Egyptian coast	317.4 TL	-0.30	0.47	0.0104	3.0617	Mehanna (2009)
Izmir Bay	278.5 TL	-1.58	0.19	0.0083	3.127	İlhan *et al.* (2009)
Edremit Bay	250.9 TL	-2.48	0.14	0.0044	3.35	Üstün (2010)
Mediterranean Sea	276 TL	0.39	0.27	-	2.925	Andalora (1981)
Catalan Sea	309.4 TL	3.85	0.11	-	-	Morales-Nin (1986)
Majorca	297.6 TL	-2.06	0.24	0.016	2.91	Morales-Nin (1991)
Majorca	312.8 TL	-2.35	0.21	0.009	3.12	Reñones *et al.* (1995)
Gulf of Gabés	212 TL (♀)	-0.65	0.43	710-6	3.12	Jabeur *et al.* (2000)
	226 TL (♂)	-1.07	0.27			
Gulf of Biscay	427 TL (♀)	0.641	0.28	-	-	N'Da *et al.* (2006)
	359 TL (♂)	0.74	0.30			
Gulf of Tunis	218.2 SL (♀)	-0.112	0.51	0.1403	3.351	Gharbi & Ktari (1981a)
	198.7 SL (♂)	-0.025	0.49	0.1443	3.28	
Catalonia	355.2 TL	-3.65	0.11	0.0073	3.1	Sanchez *et al.* (1983)
Canaries	357.1 TL	-1.84	0.22	0.0074	3.1826	Pajuelo *et al.* (1997)
English Channel	511.7 TL (♀)	-2.9	0.2	3,2810-6	3.24	Mahé *et al.* (2013)
	360.4 TL (♂)	-3.23	0.22			
Moroccan coast	392 TL	-3.21	0.3	0.0071	3.17	Bakali *et al.* (2016)
Northern Tunisian coasts	267.8 TL (♂)	-1.343	0.242	0.0061	3.216	Present study
	284.1 TL (♀)	-0.872	0.293	0.0038	3.376	
	274.6 TL (♂+♀)	-1.071	0.271	0.0036	3.327	

mullet can reach the age of 7. In that region, Andaloro and Giarritta (1985) and Reñones *et al*. (1995) recorded fish up to 6 years old, while Bougis (1952), Hashem (1973), and Morales Nin (1991) recorded them up to 3, 5, and 4 years old, respectively. According to Pajuelo *et al*. (1997), these age differences are attributable to differences in the lengths of the largest fish sampled in the various studies and the selectivity of fishing gears. Finally, the results obtained from the current study provide much information that may be useful for stock assessment and optimal management in the study area and other regions of the Mediterranean Sea.

RASTNI PARAMETRI IN STAROSTNA STRUKTURA PROGASTIH BRADAČEV *MULLUS SURMULETUS* (MULLIDAE) IZ SEVERNE TUNIZIJSKE OBALE (OSREDNJE SREDOZEMSKO MORJE)

Mourad CHÉRIF
Institut National des Sciences et Technologies de la Mer, port de pêche, 2025 La Goulette, Tunisia

Rimel BENMESSAOUD
Institut National Agronomique de Tunis, 43, Avenue Charles Nicolle 1082 -Tunis- Mahrajène, Tunisia

Christian CAPAPÉ
Laboratoire d'Ichtyologie, Université de Montpellier, 34095 Montpellier cedex 5, France
e-mail: christian.capape@umontpellier.fr

POVZETEK

Avtorji so ocenjevali starost in rast progastih bradačev, Mullus surmuletus *Linnaeus, 1758, ujetih blizu severne tunizijske obale med januarjem 2005 in decembrom 2007 na podlagi sagitalnih otolitov. Samcev je bilo več kot samic (♀/♂ = 0,56). Starostna struktura je bila od 1 do 5 let, pri čemer je glavnina primerkov pripadala starostni skupini v prvem letu. Dolžinsko-masni odnos je pokazal pozitivno alometrijo za oba spola. Prileganje von Bertalanffyjeve rastne krivulje se je med spoloma bistveno razlikovalo ($p < 0,05$): telesna dolžina $\infty = 267,8$ mm, $k = 0,242$ leto^{-1}, $t0 = -1,343$ leta za samce in telesna dolžina $TL\infty = 284,1$ mm, $k = 0,293$ leto^{-1}, $t0 = -0,872$ leta za samice.*

Ključne besede: *Mullus surmuletus*, razmerje med spoloma, rastni parametri, dolžinsko-masni odnos, Tunizija

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IMPROVEMENT OF THE ECOLOGICAL STATUS OF THE *CYMODOCEA NODOSA* MEADOW NEAR THE PORT OF KOPER

Martina ORLANDO-BONACA
Marine Biology Station Piran, National Institute of Biology, SI-6330 Piran, Fornače 41, Slovenia
e-mail: martina.orlando@nib.si

Erik LIPEJ
Ulica XXX divizije 10, SI-6320 Portorož, Slovenia

Romina BONACA
Ulica Vena Pilona 5, SI-6000 Koper, Slovenia

Leon Lojze ZAMUDA
Marine Biology Station Piran, National Institute of Biology, SI-6330 Piran, Fornače 41, Slovenia

ABSTRACT

Seagrass beds are more or less the marine counterpart of tropical rainforests, and their health is related to different anthropogenic stressors, including navigation routes and port activities. In the Mediterranean Sea, Cymodocea nodosa *is considered an effective indicator of environmental change, due to its universal distribution, sensitivity to various natural and anthropogenic pressures, and the measurability of the species' responses to impacts. The aim of this study is to present the changes in the assessment of the ecological status of the* C. nodosa *meadow near the port of Koper, which was evaluated as Bad in 2018. The results show a significant improvement in the ecological status of the meadow, which can be attributed to a reduction in anthropogenic stressors.*

Key words: *Cymodocea nodosa,* status evaluation, MediSkew index, Port of Koper, northern Adriatic Sea

MIGLIORAMENTO DELLO STATO ECOLOGICO DELLA PRATERIA DI *CYMODOCEA NODOSA* VICINO AL PORTO DI CAPODISTRIA

SINTESI

Le praterie di fanerogame marine vengono considerate la controparte marina delle foreste pluviali tropicali, e la loro salute è legata a diversi fattori di stress antropogenici, tra cui le rotte di navigazione e le attività portuali. Nel Mediterraneo, Cymodocea nodosa *è considerata un indicatore efficace del cambiamento ambientale, a causa della sua distribuzione universale, della sensibilità a varie pressioni naturali e antropogeniche, e della misurabilità delle risposte della specie agli impatti. Lo scopo di questo studio è di presentare i cambiamenti nella valutazione dello stato ecologico della prateria di* C. nodosa *vicino al porto di Capodistria, che è stato valutato come Cattivo nel 2018. I risultati mostrano un miglioramento significativo dello stato ecologico della prateria, che può essere attribuito a una riduzione dei fattori di stress antropogenici.*

Parole chiave: *Cymodocea nodosa*, valutazione dello stato, indice MediSkew, Porto di Capodistria, Adriatico settentrionale

INTRODUCTION

Seagrass meadows are among the most productive environments in the seas and oceans worldwide (Spalding *et al.*, 2003; Brodersen *et al.*, 2018). They provide habitat niches, food, and protection from predators for many different organisms in lagoons and marine ecosystems (Hemminga & Duarte, 2000; Como *et al.*, 2008; Tuya *et al.*, 2014; Espino *et al.*, 2015). These environments are also important for human well-being (Nordlund *et al.*, 2018; Unsworth *et al.*, 2018), as they provide a range of ecosystem services, including moderating wave action and thus protecting the coastline from erosion (Ondiviela *et al.*, 2014; Cabaço & Rui Santos, 2014), stabilising sediments (Terrados & Borum 2004; Widdows *et al.*, 2008), regulating nutrient cycling and sequestering carbon (Duarte *et al.*, 2010; Luisetti *et al.*, 2013), purification of seawater (Richir *et al.*, 2013), and providing a system for education and research (Effrosynidis *et al.*, 2018). For these reasons, they have been included as priority habitats in a number of legal regulations, including the European Habitats Directive (HD, 92/43/EEC).

Seagrass beds are more or less the marine counterpart of tropical rainforests, and their health is associated with various types of anthropogenic stressors. These pressures include navigation routes and port activities, seabed dredging, commercial and recreational activities such as fishing and mooring, runoff from urban and agricultural areas, wastewater, and more recently, increasing climate change and ocean acidification (Short et al., 2011; Tuya et al., 2002; Marbà et al., 2014; Orlando-Bonaca et al., 2015, 2019; Repolho et al., 2017). Such pressures affect light and nutrient resources (Hemminga & Duarte, 2000), and cause physical damage to different sea bottom types (Montefalcone *et al.*, 2008; Marbà *et al.*, 2014). Rapid and widespread declines in seagrass meadows have been reported from many coastal areas over the past fifteen years (Orth *et al.*, 2006; Tuya *et al.*, 2013; Fabbri *et al.*, 2015). Seagrasses have disappeared at a rate of 110 km^2 per year since 1980, a value similar to the rates of loss described for mangroves, coral reefs, and tropical rainforests (Waycott *et al.*, 2009). In terms of cover, one third of the world's seagrass meadows are reported to have already disappeared (Waycott *et al.*, 2009).

Four native seagrass species are found in the Adriatic Sea: *Posidonia oceanica* (Linnaeus) Delile, *Cymodocea nodosa* (Ucria) Ascherson, *Zostera marina* Linnaeus and *Zostera noltei* Hornemann (Lipej *et al.*, 2006). In the Mediterranean Sea, *C. nodosa* is considered an effective indicator of environmental change, due to its universal distribution, sensitivity to various natural and anthropogenic pressures, and the measurability of the species' responses to these impacts (Orfanidis *et al.*, 2007, 2010; Oliva *et al.*, 2012; Orlando-Bonaca *et al.*, 2015; Papathanasiou *et al.*, 2016). Although *C. nodosa* exhibits great phenotypic plasticity and can adapt to various natural and anthropogenic stressors through physiological and morphological adaptations, a sharp decline has been reported in coastal areas (Orth *et al.*, 2006; Short *et al.*, 2011; Tuya *et al.*, 2013, 2014; Fabbri *et al.*, 2015; Mačić & Zordan, 2018; Najdek *et al.*, 2020) in recent decades.

In the northern Adriatic Sea, there is still a lack of long-time data series to support the conservation status of *C. nodosa* meadows, which is included in Annex II (List of Endangered or Threatened species) of the Convention for the Protection of the Mediterranean Sea Against Pollution (the Barcelona Convention). The ecological status of *C. nodosa* meadows in the Gulf of Trieste was assessed using the MediSkew index (Orlando-Bonaca *et al.*, 2015; 2016), which was developed in accordance with the requirements of the EU Water Framework Directive (WFD, 2000/60/EC) and the Marine Strategy Framework Directive (MSFD, 2008/56/EC). The ecological status of the *C. nodosa* meadow growing near the Port of Koper was first evaluated in 2018 (Orlando-Bonaca *et al.*, 2019), and subsequently monitored in 2020 and 2021. An annual monitoring programme is planned for the future, as shipping routes and port activities are considered one of the main pressures on the

Tab. 1: Boundaries among status classes for the MediSkew index (classes High and Good indicate a Good Environmental Status).
Tab. 1: Meje med posameznimi razredi stanja za MediSkew indeks (razreda Zelo dobro in Dobro označujeta Dobro okoljsko stanje).

Status classes	Absolute values of MediSKew
High	0 ≤ MediSKew < 0.2
Good	0.2 ≤ MediSKew < 0.4
Moderate	0.4 ≤ MediSKew < 0.6
Poor	0.6 ≤ MediSKew < 0.8
Bad	0.8 ≤ MediSKew ≤ 1

status of *C. nodosa* meadows (Orlando-Bonaca *et al.*, 2015). The aim of this study is to present the changes in the assessment of the ecological status of the *C. nodosa* meadow near the port of Koper from 2018 using the MediSkew index.

MATERIAL AND METHODS

Study area, fieldwork and laboratory work

The Port of Koper is a Slovenian multi-purpose port on the northern Adriatic Sea, mainly connecting markets in Central and South-eastern Europe with the Mediterranean Sea and the Far East. The marine part of the cargo port consists of tree basins, associated mooring piers and specialized loading terminals. The highest water turbidity values were measured during manoeuvres of the large ships (Žagar *et al.*, 2014). Dredging of the sedimentary bottom was carried out in the Port of Koper along the access channels to Basin I (Luka Koper, 2015). Moreover, construction works, including dredging for the construction of a new RORO berth in the Basin III, were officially opened on May 27, 2019, and completed on March 31, 2020 (Franka Cepak, *pers. comm.*), resulting in a high sedimentation/resuspension rate.

The seagrass meadow located near the Port of Koper was sampled in July 2018, 2020 and 2021. Two sites (LuKp1 and LuKp2) were selected (Fig.

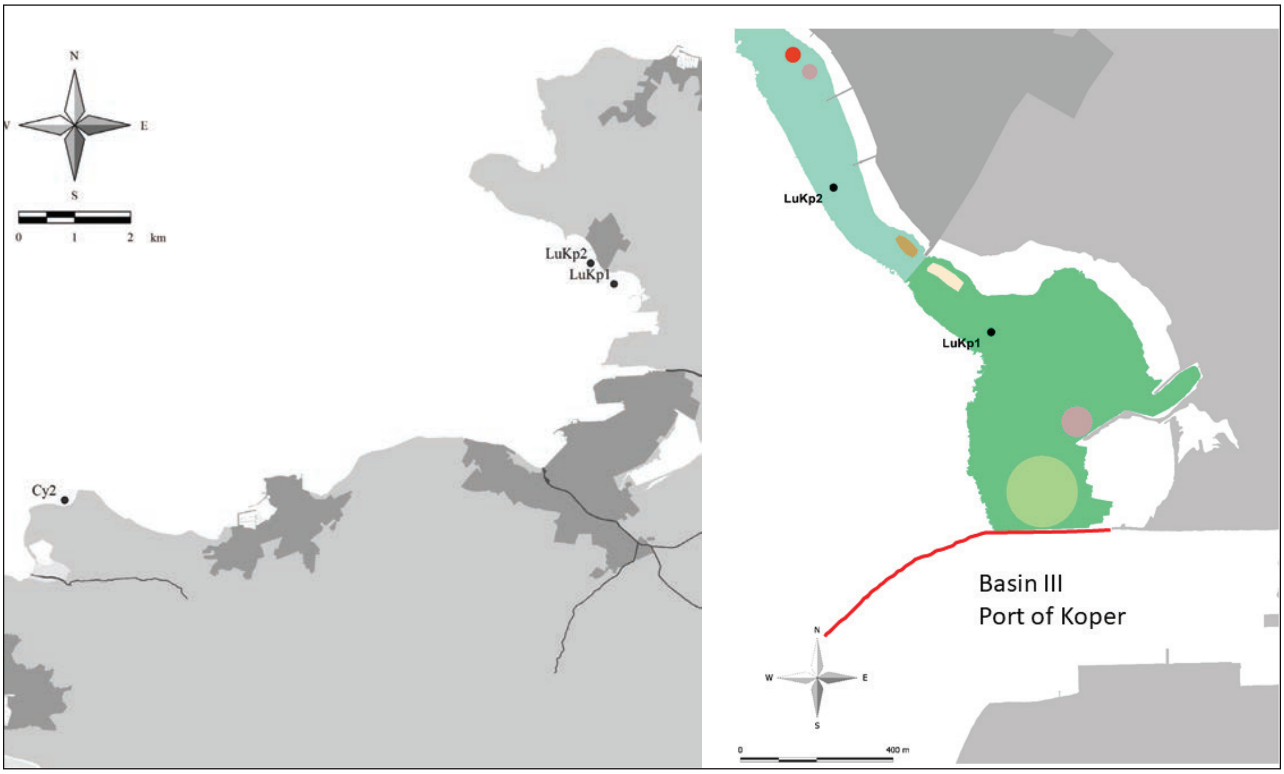


Fig. 1: Map of sampling sites for *Cymodocea nodosa* ***near the Port of Koper (LuKp1 and LuKp2) and the reference site in the Moon Bay (Cy2). The site LuKp1 is located in the part of the*** *C. nodosa* ***meadow with a higher density, while the site LuKp2 is located in a less dense part of the meadow. Other colours on the map: the largest, light green circle =*** *Zostera noltei****; grey circles = boulders with*** *Dictyota dichotoma****,*** *Padina pavonica* ***and turf; red circle = boulders with*** *Cystoseira compressa* ***and*** *P. pavonica****; dark brown area = boulders with*** *P. pavonica****,*** *Halopteris scoparia* ***and turf; light brown area = boulders with*** *Padina pavonica* ***and turf.***

Sl. 1: Zemljevid mest vzorčenja kolenčaste cimodoceje blizu Luke Koper (LuKp1 in LuKp2) in referenčno mesto vzorčenja v Mesečevem zalivu (Cy2). LuKp1 se nahaja v zelo gostem delu travnika kolenčaste cimodoceje, medtem ko se LuKp2 nahaja v manj gostem delu. Druge barve na karti: največji, svetlozeleni krog = *Zostera noltei****; sivi krogi = skale prekrite z vrstama*** *Dictyota dichotoma* ***in*** *Padina pavonica* ***ter turfom; rdeči krog = skale prekrite z vrstama*** *Cystoseira compressa* ***in*** *P. pavonica****; temno rjavo območje = skale prekrite z vrstama*** *P. pavonica* ***in*** *Halopteris scoparia* ***ter turfom; svetlo rjavo območje = skale prekrite z vrsto*** *Padina pavonica* ***in turfom.***

Tab. 2: Statistic parameters (minimum, maximum, mean, median) and absolute value of skewness (|G|) of ln-transformed lengths of photosynthetically active parts of* Cymodocea nodosa *leaves from the sampling areas near the Port of Koper (LuKp1 and LuKp2) in 2018, 2020 and 2021, and in Moon Bay (Cy2, Strunjan Nature Reserve) in 2018. The reference median value in 2018 was 13.95 cm.
Tab. 2: Statistični parametri (minimum, maksimum, povprečje, mediana) in absolutna vrednost koeficienta asimetrije (|G|) ln-transformiranih dolžin fotosintetsko aktivnega dela listov kolenčaste cimodoceje* (C. nodosa) *na točkah vzorčenja blizu Luke Koper (LuKp1 in LuKp2) v 2018, 2020 in 2021 ter v Mesečevem zalivu (Cy2, Naravni rezervat Strunjan) v 2018. Referenčna mediana v 2018 je bila 13,95 cm.

Area	Date	Min length (cm)	Max length (cm)	Mean (cm)	Median (cm)	|G|
Str_3	12.7.2018	5.4	30.5	14.5	**13.95**	0.261
Str_4	12.7.2018	8.1	22.7	13.5	13.20	**0.022**
LuKp1_1	17.7.2018	5.9	**66.2**	37.8	41.25	1.423
LuKp1_2	17.7.2018	6.0	57.1	34.7	37.05	1.162
LuKp2_1	17.7.2018	3.7	58.8	30.7	30.45	**1.533**
LuKp2_2	17.7.2018	6.9	52.2	27.3	28.25	1.130
LuKp1_1	14.7.2020	5.4	62.5	32.0	31.90	1.044
LuKp1_2	14.7.2020	7.4	57.7	29.9	29.25	0.706
LuKp2_1	14.7.2020	5.1	61.3	29.2	28.90	0.979
LuKp2_2	14.7.2020	7.3	55.9	31.4	31.25	0.955
LuKp1_1	1.7.2021	8.7	55.8	27.33	25.90	0.355
LuKp1_2	1.7.2021	7.3	57.1	28.12	27.20	0.442
LuKp2_1	1.7.2021	11.5	47.7	24.72	22.95	0.142
LuKp2_2	1.7.2021	5.7	46.2	24.15	23.15	0.659

1) along the same isobath (3 m) and, within each site, two areas (LuKp1_1, LuKp1_2, and LuKp2_1, LuKp2_2) were chosen, approximately 100 m apart. In each area, five metallic frames (25 cm x 25 cm) were randomly placed on the bottom by SCUBA divers. These five squares were considered replicates of one sample. All shoots of *C. nodosa* located in each frame were carefully uprooted. The samples were labelled and individually placed in plastic bags.

In July 2018, samples of *C. nodosa* were also collected in the Strunjan Nature Reserve (sampling site Cy2, areas Str_3 and Str_4). Due to the low Pressure Index for Seagrass Meadows (PISM) value, the area Str_3 was selected as the reference area for *C. nodosa* in the Gulf of Trieste in 2009 (Orlando-Bonaca *et al.*, 2015), and it has to be sampled and assessed every 5 years.

The samples of *C. nodosa* were stored in a freezer at −20°C in the laboratory of the Marine

Tab. 3: MediSkew index values for the sampling areas of* Cymodocea nodosa *in the Port of Koper and in the Moon Bay (Strunjan) and assessment of the Ecological Status (according to the WFD) and Environmental Status (according to the MSFD).
Tab. 3: Vrednosti indeksa MediSkew na točkah vzorčenja s kolenčasto cimodocejo in opredelitev ekološkega stanja (glede na OVS) in okoljskega stanja (glede na ODMS) za morski travnik ob Luki Koper in v Mesečevem zalivu (Strunjan).

Year	Area	Area's MediSkew	Site's MediSkew	Meadow's MediSkew	Ecolog. Status	Environ. Status	N of leaves	N of adult leaves
2018	Str_3	0.065	0.04	-	High	Good / Achieved	300	213
	Str_4	0.024					300	218
	LuKp1_1	1.00	0.935	0.825	Bad	Not good / Not achieved	300	225
	LuKp1_2	0.87					300	204
	LuKp2_1	0.79	0.715				300	247
	LuKp2_2	0.64					300	218
2020	LuKp1_1	0.71	0.635	0.640	Poor	Not good / Not achieved	**251**	**181**
	LuKp1_2	0.56					300	223
	LuKp2_1	0.62	0.645				300	246
	LuKp2_2	0.67					300	222
2021	LuKp1_1	0.39	0.415	0.37	Good	Good / Achieved	300	238
	LuKp1_2	0.44					300	207
	LuKp2_1	0.26	0.325				300	231
	LuKp2_2	0.39					300	212

Biology Station Piran. The day before the analysis, they were slowly defrosted in a refrigerator. Seagrass shoots were then kept in plastic wash basins containing seawater. Twenty shoots from each quadrat were randomly selected (Orfanidis *et al.*, 2007). For each leaf (usually 5-6 leaves per shoot), the following parameters were measured to the nearest mm: length of the leaf sheath, length of the photosynthetic part and its width. The age of the leaf was designated as adult (when the leaf sheath was well-developed), intermediate (when the leaf sheath was weakly developed at the leaf base), and juvenile (when the leaf sheath was absent). The above measurements were made on at least 60 undamaged, photosynthetically active leaves (adult and/or intermediate) from each frame. One sample consisted of five replicates of 60 leaves (300 leaves in total).

Additionally, in May 2020, the meadow and other vegetation types in the area were checked by

applying a field method based on visual observation of sea-bottom segments covered with vegetation in the infralittoral belt. The survey consisted of a cruise along the coastline in a small boat. Sublittoral communities were identified using a large Aquascope Underwater Viewer and directly annotated in a graphic display. This graphic support was prepared at an appropriate small scale and was suitable for use in the field. The final result is a division of the shoreline into several sectors, each identified by a community category (see Fig. 1). The information obtained on the distribution of communities was transcribed into a georeferenced graphic support in a Geographical Information System. All vegetation types between 1 and 4 m depth, were mapped.

Data analysis

To quantify changes in the photosynthetic part of the leaf length distribution for each *C. nodosa* sampling area near the Port of Koper, the MediSkew index was calculated (for details, see Orlando-Bonaca *et al.*, 2015). The boundaries among the status classes for the MediSkew index were set equidistantly (Tab. 1). Five status classes are sufficient for the assessment of the Ecological Status (ES) according to the WFD. In addition, High and Good classes indicate Good Environmental Status (EnS) according to the MSFD, while the classes Moderate, Poor, and Bad are considered Not Good EnS.

RESULTS AND DISCUSSION

The surveyed *C. nodosa* meadow near the Port of Koper can be considered as a part of the biocoenosis of superficial muddy sands in sheltered waters. The part of the meadow closest to the Port of Koper has a higher density of shoots than the part to the north (different green colours in Fig. 1). Within the meadow, rocky biotopes were also found, which include small communities dominated by *Padina pavonica* (Linnaeus) Thivy, *Dictyota dichotoma* (Hudson) J.V. Lamouroux*, Halopteris scoparia* (Linnaeus) Sauvageau and *Cystoseira compressa* (Esper) Gerloff & Nizamuddin. A monospecific patch of *Zostera noltei* was also found close to the Port (see Fig. 1).

The parameters of *C. nodosa* per sampling area are shown in Table 2. The leaves of *C. nodosa* were significantly shorter in the areas within the reference site in the Moon Bay (Cy2) than in the areas near the Port of Koper in all years, and consequently so were the median values (Tab. 2). The skewness |G| was the highest in the LuKp2_1 area in 2018 (Tab. 2). However, the results show that mean and median leaf length values decreased in all sampled areas in the Port of Koper in 2020 and additionally in 2021. Leaf lengths were still much longer than those at the reference area, but there is a very clear trend of decreasing leaf lengths since 2018 near the Port of Koper (Tab. 2).

It should be emphasized that in 2020, many adult leaves of *C. nodosa* at LuKp1_1 were broken, without apical parts, and therefore we could not measure 300 undamaged leaves for this area (Tab. 3), as indicated in the methodology. All samples collected in 2021 had fewer damaged leaves and the number of adult leaves of *C. nodosa* exceeded 200 per sample (Tab. 3).

The ES (according to WFD) and the EnS (according to MSFD) of sampling areas and sites were assessed according to the boundaries in Table 1. The MediSkew index values for each sampled area in the Port of Koper are presented in Table 3. The two areas of the sampling site LuKp2, furthest from the Port Basin III, improved the ES from Poor in 2018 and 2020 to Good in 2021.

The improvement in the status of the LuKp1 sampling site is also impressive (Tab. 3). The area LuKp1_2 was assessed as Bad ES in 2018, while it remained Moderate in 2020 and 2021. The area LuKp1_1 improved from Bad ES in 2018 to Poor in 2020 and to Good in 2021. The ES of the entire meadow of *C. nodosa* near the Port of Koper was evaluated as Good in 2021, which is two orders of magnitude better than in 2020 (Tab. 3).

The results obtained from 2018 to 2021 show a significant improvement in the ES of the *C. nodosa* meadow. The Good ES achieved in 2021 may be related to the reduction of anthropogenic pressures, as the construction of the new RORO berth was completed in March 2020. This construction resulted in higher sediment resuspension in recent years, leading to increased turbidity and consequently less light. Seagrasses are generally light-limited (Touchette & Burkholder, 2000). Thus, when exposed to low light levels due to high water turbidity, they respond by increasing biomass distribution to the leaves. The increase in leaf size allows marine plants to capture more light and convert it into photosynthetic production (Greve & Binzer, 2004). That resuspension of sediments and water turbidity are critical to the health of *C. nodosa* meadows is confirmed by recent research (Orfanidis *et al.*, 2020). Additionally, the decrease in anthropogenic pressures near the port area in 2020 was also influenced by the Covid-19 pandemic, which led to a decrease in maritime traffic, especially cruise ship traffic in the Port of Koper,

as reported in many local media. March et al. (2021) have attempted to assess the impact of the pandemic on maritime traffic globally, which in turn has implications for the blue economy and ocean health.

The results of the present study are very encouraging, and as the Port of Koper has prepared a long-term monitoring programme in the harbour area and its surroundings, we hope to confirm the improved ES of the *C. nodosa* meadow near the Port in the long term.

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IZBOLJŠANJE EKOLOŠKEGA STANJA MORSKEGA TRAVNIKA KOLENČASTE CIMODOCEJE (*CYMODOCEA NODOSA*) V BLIŽINI KOPRSKEGA PRISTANIŠČA

Martina ORLANDO-BONACA
Morska biološka postaja Piran, Nacionalni inštitut za biologijo, SI-6330 Piran, Fornače 41, Slovenia
e-mail: martina.orlando@nib.si

Erik LIPEJ
Ulica XXX divizije 10, SI-6320 Portorož, Slovenia

Romina BONACA
Ulica Vena Pilona 5, SI-6000 Koper, Slovenia

Leon Lojze ZAMUDA
Morska biološka postaja Piran, Nacionalni inštitut za biologijo, SI-6330 Piran, Fornače 41, Slovenia

POVZETEK

Morski travniki so bolj ali manj morski ekvivalent tropskega deževnega gozda, njihovo zdravje pa je povezano z različnimi antropogenimi dejavniki, vključno s plovnimi potmi in pristaniškimi dejavnostmi. V Sredozemskem morju je kolenčasta cimodoceja (Cymodocea nodosa) *zaradi svoje univerzalne razširjenosti, občutljivosti na različne naravne in antropogene pritiske ter merljivosti odzivov vrste na vplive, učinkovit kazalnik okoljskih sprememb. Namen študije je predstaviti spremembe v oceni ekološkega stanja morskega travnika kolenčaste cimodoceje v bližini koprskega pristanišča, ki je bilo 2018 opredeljeno kot Zelo slabo. Rezultati kažejo bistveno izboljšanje ekološkega stanja travnika, kar lahko pripišemo zmanjšanju antropogenih pritiskov.*

Ključne besede: *Cymodocea nodosa,* ocena stanja, MediSkew indeks, Luka Koper, severni Jadran

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CESTUM VENERIS LESUEUR, 1813 (CTENOPHORA) – A RARE GUEST IN THE NORTHERN ADRIATIC SEA

Manja ROGELJA
University of Primorska, Aquarium Piran, Kidričevo nabrežje 4, 6330 Piran, Slovenia
e-mail: manja.rogelja@upr.si

Martin VODOPIVEC & Alenka MALEJ
Marine Biology Station Piran, National Institute of Biology, SI-6330 Piran, Slovenia
e-mail: alenka.malej@nib.si

ABSTRACT

We report the occurrence of the ctenophore Cestum veneris *Lesueur, 1813 in the Gulf of Trieste (northern Adriatic Sea). Three individuals were found in March 2022, representing the first documented record in the scientific literature in more than 130 years. They were observed and photographed in the sea, and two specimens were brought to the Piran Aquarium, where their behaviour was observed. Historical and recent literature on the occurrence of this species in the Adriatic Sea was reviewed. The occurrence in the Gulf of Trieste is likely related to the transport of* C. veneris *with the currents, and therefore we present simulation results for the period January-February. Despite the relatively rare detections near the coast, this species is probably widespread in the offshore waters of the central and southern Adriatic.*

Key words: winter gelatinous plankton, Ctenophora, distribution, Gulf of Trieste

CESTUM VENERIS LESUEUR, 1813 (CTENOPHORA) – OSPITE RARO NELL'ADRIATICO SETTENTRIONALE

SINTESI

Gli autori segnalano la presenza dello ctenoforo Cestum veneris *Lesueur, 1813 nel Golfo di Trieste (mare Adriatico settentrionale). A marzo 2022 sono stati avvistati tre esemplari, che rappresentano il primo ritrovamento documentato dopo oltre 130 anni. Osservati e fotografati prima in mare, due esemplari sono stati portati all'Acquario di Pirano, dove è stato seguito il loro comportamento. È stata esaminata la letteratura storica e recente sulla presenza di questa specie nel mare Adriatico. Gli avvistamenti nel Golfo di Trieste sono probabilmente legati al trasporto di* C. veneris *con le correnti, e nell'articolo vengono presentati i risultati della simulazione per il periodo gennaio - febbraio. Nonostante i rilevamenti relativamente rari in prossimità della costa, questa specie è probabilmente diffusa nel mare aperto dell'Adriatico centro-meridionale.*

Parole chiave: plancton gelatinoso invernale, Ctenophora, distribuzione, Golfo di Trieste

INTRODUCTION

Plankton in the northern Adriatic, including the Gulf of Trieste, is affected in winter and early spring not only by the well-mixed and cold water, but also by the greater influx of water from the south (Zavatarelli & Pinardi, 2003), which brings some otherwise rare species to this northernmost part of the Adriatic (Fonda Umani *et al.*, 1992). These dynamics also affect the structure of the gelatinous plankton community. According to Miloš & Malej (2005), the cold-water group of gelatinous mesozooplankton was more diverse and less abundant, while some organisms originating from the deep southern waters of the Adriatic, such as the siphonophore *Vogtia pentacantha*, were occasionally observed. The most common winter-spring macrojellyfish in the northern Adriatic included the syphozoans *Aurelia solida*, *Rhizostoma pulmo*, the hydrozoan *Aequorea forskalea*, and the ctenophore *Leucothea multicornis*, while *Cestum veneris* was observed in the central and southern Adriatic and only in a few years in the northern Adriatic (Pestorić *et al.*, 2021).

C. veneris is a tentaculate ctenophore species that lives circumglobally in temperate, subtropical and tropical seas (Mayer, 1912; GBIF, 2019). It is considered epipelagic (Harbison *et al.*, 1978), but has also been observed in the mesopelagic zone (Lindsay *et al.*, 2015; Hidaka *et al.*, 2021).

Péron and Lesueur, who found this gelatinous species in coastal waters near Nice, France, on 12 May, 1809, named it after the magical girdle of Aphrodite - Ceste de Venus - and assigned this beautiful new ctenophore *C. veneris* with a distinctly elongated and transversely compressed body to the beroids (Lesueur, 1813). However, they had only one specimen available for examination. Lesueur reported in the same note (1813) that this organism, unknown to him and his collaborator Péron, was occasionally observed in large numbers in the harbour of Villefranche, where it was called by fishermen 'sabres de mer' (a sea saber, a kind of curved sword used especially by pirates). Later Gegenbaur (1856) created the order Cestida and the family Cestidae, which today includes two monotypic genera: *Cestum veneris* Lesueur 1813 and *Velamen parallelum* Krumbach 1925.

In our contribution, we reviewed the historical and current literature on the occurrence of *C. veneris* in the Adriatic Sea. The recent discovery of this organism in the Gulf of Trieste, the first documented after 138 years (Graeffe, 1884), prompted us to describe its distribution and discuss some ecological characteristics of this beautiful ctenophore. We also present modelling results of the winter circulation, which likely support the entry of planktonic organisms of more southern origin into the northern Adriatic and the Gulf of Trieste.

MATERIAL AND METHODS

In total, three specimens of *C. veneris* were observed, two on 2 March and one on 3 March 2022 near the coast of Piran, Gulf of Trieste. The first observed specimen was not visible from the surface, but was accidentally felt by hand while taking underwater photos. During the capture, a part of the animal broke off, so the ctenophore was immediately released after inspection. At the same time, another specimen was observed 20 m away and collected undamaged. The next day, a third specimen was found at the same location and was also collected. The sea temperature was 8°C, salinity 38.6 and the sea surface near the shore was calm with almost no waves.

Two captured specimens were brought to the Piran Aquarium, but the specimen collected on March 2 began to disintegrate very quickly. The specimen caught on March 3 was immediately transferred to the 325 litres kreisel tank with a water temperature of 13°C and salinity of 38. It was fed freshly hatched *Artemia* nauplii. Photos and videos were taken, but the quality

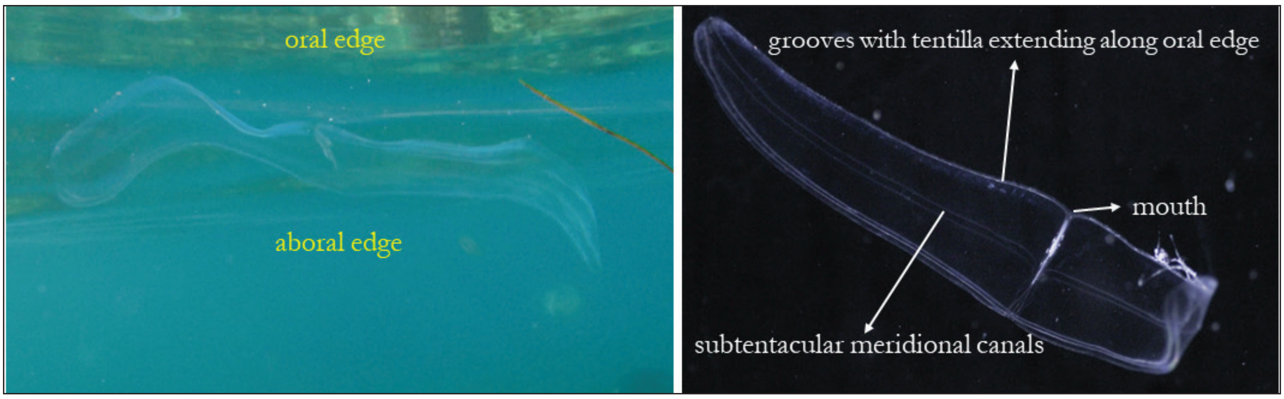


Fig. 1: Photo of *Cestum veneris* ***in the sea (left) and in the aquarium (right).***
Sl. 1: Fotografija *Cestum veneris* ***v morju (levo) in v akvariju (desno).***

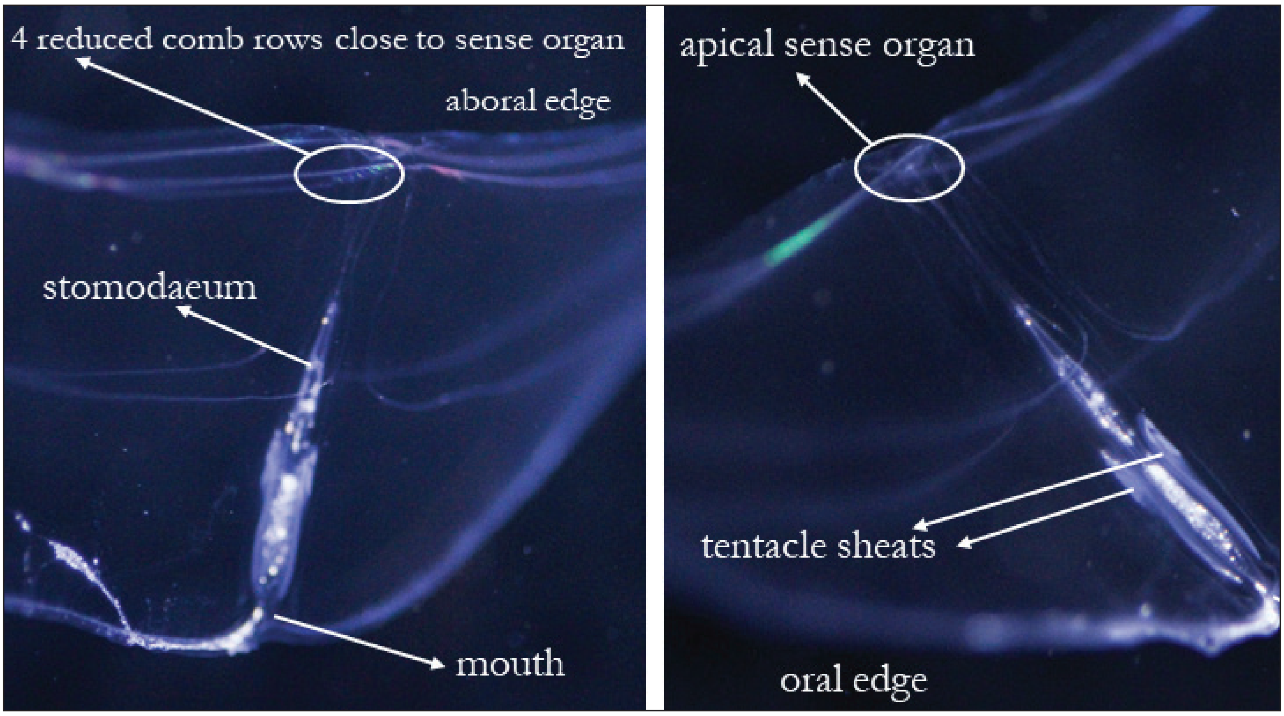


Fig. 2: Characteristics of the central part of *Cestum veneris****.***
Sl. 2: Značilnosti osrednjega dela *Cestum veneris****.***

was not very good due to the great transparency and rapid movements of the *C. veneris*.

We reviewed the available published sources on ctenophores in the Adriatic Sea in the last 150 years since the first description of *C. veneris*. With regard to the ecology of this species, we also consulted other published sources. The global distribution of *C. veneris* shown in Fig. 2 is from the Global Biodiversity Information Facility database (GBIF, 2019).

The CROCO ocean model (Coastal and Regional Ocean COmmunity model, formerly known as ROMS_AGRIF; www.croco-ocean.org) was used to simulate the Adriatic circulation during the 2000-2018 period. The model configuration was similar to the one used in Vodopivec *et al.* (2017), but with horizontal resolution reduced to 4 km and new atmospheric forcing provided by ERA5 (Hersbach *et al.*, 2020). Barotropic currents and free surface were averaged over the entire simulation period for January and February to provide an overview of the general circulation during the months when the *Cestum veneris* was likely transported from the central to the northern Adriatic.

RESULTS AND DISCUSSION

In the current classification, *C. veneris* is listed as a single species of the genus, belonging to the family Cestidae along with another monotypic genus *Velamen* Krumbach 1925 (Mills, 1998 - present):

Phylum Ctenophora
Class Tentaculata
Order Cestida Gegenbaur 1856
Family Cestidae Gegenbaur 1856
Genus *Cestum* Gegenbaur 1856
Species *Cestum veneris* Lesueur 1813

C. veneris is characterised by a transparent, ribbon-shaped body, flattened in the tentacular axis while the lobular axis is elongated (Fig. 1). Adults can reach a height of about 8 cm and a length up to nearly 1,5 m but usually less than 80 cm. In contrast to those in g. *Velamen,* where subtentacular meridional canals arise directly without bending, in *Cestum* they arise from the stomodaeum then bend outward and run along the midline of the body. Substomodeal comb rows are greatly elongated, while four subtentacular ones are rudimentary on aboral edge close to the sense organ (Fig. 2). On both sides of the mouth, grooves with tentilla extend along the entire oral margin of the body. Gonads run in continuous line under substomodaeal meridional canals.

All Ctenophora are carnivorous and their feeding mode is related to their morphology: they forage with tentacles, lobes, or feed by engulfing the prey (Haddock, 2007). *C. veneris* search for prey hovering or gliding horizontally with the oral edge leading (Matsumoto & Harbison, 1993) and tentilla stream aborally like curtains. After a few meters, *Cestum*



Fig. 3: Global distribution of *Cestum veneris* ***(https://www.gbif.org/species/2501198).***
Sl. 3: Globalna razširjenost rebrače *Cestum veneris* ***(https://www.gbif.org/species/2501198).***

move vertically and reverse swimming direction. Tentillae with sticky colloblasts attach to prey such as small copepods and then contract. Prey items are transferred to the oral grove and moved toward the mouth using cilia (Matsumoto & Harbison, 1993). Besides comb-row hovering or gliding, *Cestum* can also swim by muscular body undulations (Ceccaldi, 1972).

Cestum veneris distribution

Cestum veneris is probably one of the most fragile ctenophores. Therefore, it is not surprising that we cannot catch them with conventional nets, which have been most commonly used in plankton surveys in the past. This characteristic, therefore, has a major impact on assessing *C. veneris* distribution and abundance. Nevertheless, researchers in the past have described the distribution of this species based on observations either from the coast or during research cruises. Their distribution was studied in particular during the 'first golden age of gelata research', from the late 19th to the early 20th century (Haddock, 2004), when many new species of Ctenophora were described, (Chun, 1878; Bigelow, 1904; Mayer, 1912). The development of autonomous diving, remote sensing, and new *in situ* observation techniques improved the collection of data on delicate gelatinous organisms. In addition, citizen science has enabled the collection of large amounts of data over broad areas and long periods of time. The availability of photographs and video clips facilitated the recognition of observed organisms by experts. Today, platforms such as Mer et littoral - European Marine Life or Global Biodiversity Information Facility provide information on the distribution of many marine species, including *C. veneris* (Fig. 3).

There are relatively few published data on ctenophores in the Adriatic Sea (Pestorić *et al.*, 2021). The rare records of ctenophores are usually not the result of systematic studies of these gelatinous organisms but are rather based on incidental observations such as ours. Some evidence come from published regular plankton observations for those species that are better preserved and later from the establishment of citizen science programs. The non-native *Mnemiopsis leidyi* is more systematically studied and is therefore a rare exception due to its significant impact on the ecosystem (Malej *et al.*, 2017; Budiša *et al.*, 2021).

The first record of *C. veneris* from the Adriatic Sea dates back to the 19th century when Graeffe (1884) reported rare, occasional observations of single specimens in the Gulf of Trieste. Krumbach (1911) found four specimens near Rovinj in mid-December 1910; two were about 10 cm and two about 25 cm long. In the southern Adriatic, Babić (1913) reported one small specimen observed near the island of Mljet in March 1912 and three larger specimens (about 50 cm) near Komiža (island of Vis). These few observations suggest that *C. veneris* was rare in the Adriatic, but Benović & Lučić (2001) described massive strandings and swarms near the island of Korčula and Dubrovnik after strong southerly winds. For more information on temporal and spatial distribution of *C. veneris* in the Adriatic, see Pestorić *et al.* (2021) and Violić *et al.* (2022). It was described as common in the central and southern Adriatic in winter and formed blooms in some years (1999, 2013). In the northern Adriatic, only few individuals were recorded in 2015-2017 period, while none were observed in the Gulf of Trieste (Pestorić *et al.*, 2021). Also, in the checklist of Ctenophora in the Italian seas (Mills, 2008), *C. veneris* was listed only for the central

and southern Adriatic. In the Mediterranean (Gulf of Naples), blooms of *C. veneris* were reported by Chun (1878) between December and May. Harbison et al. (1978), presenting the distribution and natural history of oceanic ctenophores of the North Atlantic, reported that *C. veneris* was the most abundant ctenophore species, and its density exceeded 1 per m^3 at some stations.

Being an oceanic species, it is not surprising that it is so rare in the shallow northern Adriatic and Gulf of Trieste. Our observation of *C. veneris* in March 2022 is the first from the Gulf of Trieste (Fig. 2) since the report of Graeffe (1884). All three observed specimens were in shallow water, had a rectilinear posture, and swam just below the sea surface. They were swimming by bending, which resembled a wave moving from one side of their body to the other. The undulation started on the side of their body where the movement was directed and ran over to the other side like a wave. They could swim in either direction by changing sides at the beginning of the bend. Similar behaviour of individuals up to 80 cm in length was observed in diving by Ceccaldi (1972), who also noticed curling (rolling upon itself) in captivity and attributed this behaviour to stress.

Our observations in the aquarium agree with those of Ceccaldi (1972). Immediately after release into the kreisel tank, the *Cestum* curled up and remained in this shape for some time. Then it slowly stretched and moved in the same manner as it had previously been observed in the sea. In the following hours it was mostly fully stretched and moved with the circular flow of the water. A continuous movement of the cilia was observed. *Cestum* also ate newly hatched *Artemia* nauplii offered as food, as individual nauplii were observed in the stomach in the following hours (Fig. 2). During this time, it moved effortlessly and remained undamaged. The length was roughly estimated at 40 to 50 cm, measured by the size of the container in which they were held.

The rare sporadic records in the northern Adriatic and the Gulf of Trieste (Graeffe, 1884; Krumbach, 1911; Pestorić *et al.*, 2021; this article) during winter are likely due to the transport of *C. veneris* with the currents. This assumption is supported by the modeled barotropic currents for January and February, shown in Figure 4. The northward current along the eastern Adriatic coast is clearly visible. It passes the Kvarner Bay (KV) and splits into two branches at the southern tip of the Istrian peninsula (IS). The stronger branch veers westward and crosses the basin, while the weaker branch travels further north towards the Gulf of Trieste (GT).

The presence of *C. veneris* in the Gulf of Trieste in March 2022 could be caused by a bora (strong NE wind) event lasting several days, which occurred shortly before its discovery. A study of topographic control of wind-driven circulation has shown that the bora induces a compensating current on the south-eastern side of the Gulf of Trieste (Malačič *et al.*, 2012 - Figure 7). The leeward current (flowing into the gulf) is present almost throughout the entire water column, except for a few meters below the surface, where the current is windward. The inflowing north-eastward current could be responsible for the transport of the *C. veneris* individuals into the Gulf of Trieste.

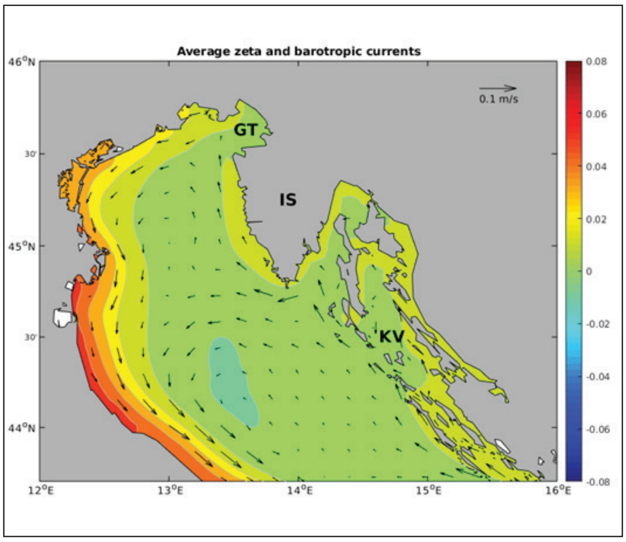


Fig. 4: Average January and February barotropic currents and free surface for the 2000-2018 period (model results). The arrow top-right represents current speed of 0.1 m/s, the colour scale is in meters. Arrows are plotted for every fourth grid cell. GT – Gulf of Trieste, IS – Istrian peninsula, KV – Kvarner Bay.
Sl. 4: Povprečni barotropni tokovi in prosta gladina v januarju in februarju za obdobje 2000-2018 (modelski rezultati). Puščica v desnem zgornjem kotu slike predstavlja tok s hitrostjo 0.1 m/s. Barvna skala je v metrih. Puščice so narisane za vsako četrto točko modelske mreže. GT – Tržaški zaliv, IS – Istra, KV – Kvarner.

In summary, despite the relatively rare finds near the Adriatic coasts, especially in the shallow northernmost area, this species is probably widespread in the offshore waters of the central and southern Adriatic.

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CESTUM VENERIS LESUEUR, 1813 (CTENOPHORA) – REDEK GOST V SEVERNEM JADRANU

Manja ROGELJA
Univerza na Primorskem, Akvarij Piran, Kidričevo nabrežje 4, 6330 Piran, Slovenia
e-mail: manja.rogelja@upr.si

Martin VODOPIVEC & Alenka MALEJ
Morska biološka postaja Piran, Nacionalni inštitut za biologijo, Fornače 41, SI-6330 Piran, Slovenia
e-mail: alenka.malej@nib.si

POVZETEK

*Avtorji poročajo o redkem pojavu rebrače venerin pas (*Cestum veneris *Leseuer, 1813) v Tržaškem zalivu (severni Jadran). Trije osebki venerinega pasu so bili opaženi marca 2022, kar je prva v znanstveni literaturi dokumentirana najdba po več kot 130 letih. Osebke smo opazovali in fotografirali v morju, dva pa prenesli tudi v Akvarij Piran, kjer smo opazovali obnašanje. Pregledali smo historično in novejšo literaturo o pojavljanju te vrste rebrač v Jadranskem morju. Pojav venerinega pasu v Tržaškem zalivu povezujemo z vnosom oz. transportom vodnih mas iz južnejših delov. Na osnovi nekaterih objav za Jadransko in Sredozemsko morje ter opazovanj v severnem Atlantiku sklepamo, da je ta vrsta, kljub ne ravno pogostim opažanjem v priobalnih vodah, dokaj običajna v odprtih vodah srednjega in južnega Jadrana.*

Ključne besede: zimski želatinozni plankton, Ctenophora, razširjenost, Tržaški zaliv

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NOTOSPERMUS ANNULATUS (NEMERTEA: LINEIDAE), A NEW RECORD FOR BOSNIA AND HERZEGOVINA

Adla KAHRIĆ & *Dalila DELIĆ*
Center for marine and freshwater biology Sharklab ADRIA, Paromlinska 16, 71 000 Sarajevo, Bosnia and Herzegovina
e-mail: adla.k@hotmail.com

Dejan KULIJER
National Museum of Bosnia and Herzegovina, Zmaja od Bosne 3, 71 000 Sarajevo, Bosnia and Herzegovina

ABSTRACT

The first record of the ribbon worm Notospermus annulatus *(Grube, 1840) in Bosnia and Herzegovina is presented. For a long time, it was regarded as a synonym of* Notospermus geniculatus *(Delle Chiaje, 1822), but based on recent molecular phylogenetic study its status as a separate species is proposed and followed in this paper. A single specimen was recorded on 2nd October 2021 in a small bay near Opuće Village on Klek Peninsula. This finding contributes to the understanding of the species' distribution in the Adriatic Sea and expands the knowledge of a scarcely known national marine fauna. This is also the first record of any Nemertea species in marine waters in Bosnia and Herzegovina.*

Key words: Adriatic Sea, Neum Bay, distribution, marine fauna, Mediterranean

NOTOSPERMUS ANNULATUS (NEMERTEA: LINEIDAE), UN NUOVO RITROVAMENTO PER LA BOSNIA ED ERZEGOVINA

SINTESI

L'articolo presenta il primo ritrovamento del verme a nastro Notospermus annulatus *(Grube, 1840) in Bosnia ed Erzegovina. Per molto tempo è stato considerato un sinonimo di* Notospermus geniculatus *(Delle Chiaje, 1822), ma sulla base di un recente studio di filogenetica molecolare il suo status di specie separata viene proposto e seguito in questo articolo. Un singolo esemplare è stato trovato il 2 ottobre 2021 in una piccola baia vicino al villaggio di Opuće, nella penisola di Klek. Questo ritrovamento contribuisce alla comprensione della distribuzione della specie nel mare Adriatico e amplia la conoscenza di una fauna marina nazionale poco conosciuta. Si tratta inoltre del primo ritrovamento di una specie di Nemertea nelle acque marine della Bosnia ed Erzegovina.*

Parole chiave: mare Adriatico, Baia di Neum, distribuzione, fauna marina, Mediterraneo

INTRODUCTION

Around 1300 species of nemerteans have been reported globally (Gibson, 1995; Sundberg & Gibson, 2008; Norenburg *et al*., 2021). Most of them inhabit marine environment and rarely freshwater and terrestrial habitats, with majority of species living in benthic habitats. Benthic species are largely carnivorous predators feeding on different organisms, primary polycheates and crustaceans, some are egg predators such as *Carcinonemertes* spp. (Kuris, 1993), while other rarely base their diet on recently dead organisms (McDermott & Roe, 1985; Thiel, 1998). Generally, the knowledge of biology, ecology and distribution of this group is limited, probably due to challenges in collection, identification and preservation of specimens (e.g. Junoy & Herrera-Bachiller, 2010; Fernández-Álvarez *et al*., 2015).

Within lineid heteronemerteans identified as *Notospermus geniculatus* (Delle Chiaje, 1822) in the Mediterranean, three nominal species have been proposed: *Polia geniculata* Delle Chiaje, 1822; *Notospermus drepanensis* Huschke, 1830; and *Meckelia annulata* Grube, 1840 (Kajihara *et al*., 2022). They were synonymized by several authors, including Riser (1991). However, based on the molecular phylogenetic study from Kajihara *et al*. (2022), at least two biological entities exist within *Notospermus* in the Mediterranean, and they can be distinguished based on the appearance of the white rings on the dorsal side of the body. The name *Notospermus annulatus* (Grube, 1840) was assigned to the one having the white rings dorsally discontinuous, aside from the anterior-most one, as this was the species character in its original description and illustration by Grube (1840) (Kajihara *et al*., 2022). The species was originally described as *Meckelia annulata* Grube, 1840 from Naples and Palermo, Italy (Grube, 1840).

Notospermus annulatus has flattened rather than rounded body. The color is dark green, with intermittent, not quite closed white ring lines lying at fairly equal distances (Grube, 1840).

There are limited data about the distribution of the species. Considering that was regarded as a synonym of *N. geniculatus* it was mostly reported under this name (*e.g*. Kvist *et al*., 2014; Insacco *et al*., 2021). Records of *N. annulatus* are known from Spain, France, Italy, Croatia (Senz, 1998; Kajihara *et al*., 2022).

So far, studies on marine ribbon worms were never conducted in Bosnia and Herzegovina, so this record of *Notospermus annulatus* represents the first record of phylum Nemertea for the marine fauna of the country.

MATERIAL AND METHODS

A single specimen of *N. annulatus* was found at midday of 2nd October 2021 during the short field study in a small bay at the outskirts of Opuće Village (Figs. 1 and 2). This small bay is located on Klek Peninsula, at the entrance to the Neum Bay that represents the major part of the sea territory of Bosnia and Herzegovina. The Neum Bay is approximately 6 km long, 1.2 km wide and up to 30 m deep bay located in central part of Eastern Adriatic Sea coast, completely enclosed by

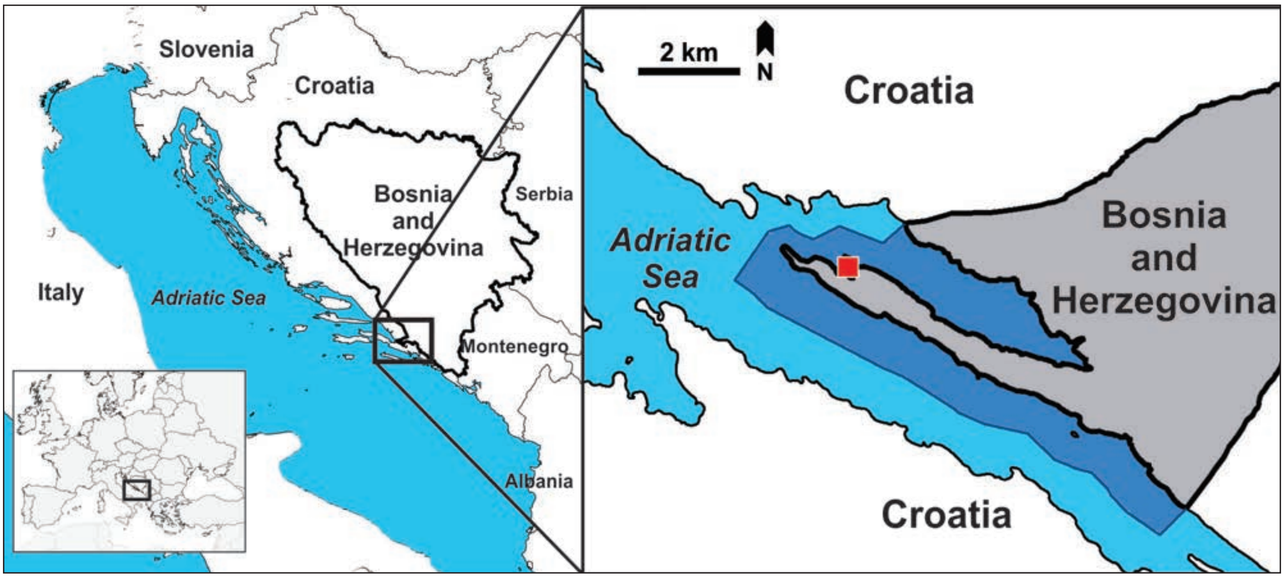


Fig. 1: The study area and the location (square mark) where* Notospermus annulatus *(Grube, 1840) was recorded.
Sl. 1: Zemljevid obravnavanega območja z lokaliteto najdbe (kvadratek) primerka vrste* Notospermus annulatus *(Grube, 1840).

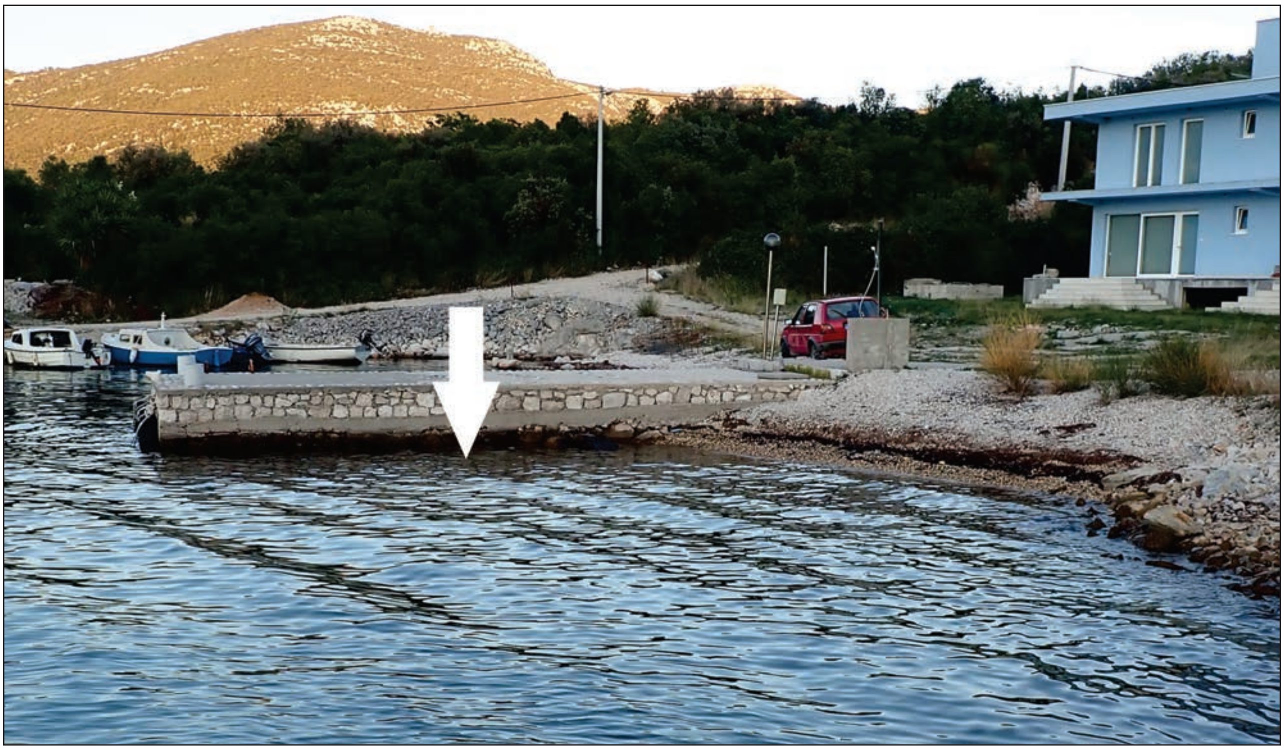


Fig. 2: The finding location and the habitat of *Notospermus annulatus* ***(Grube, 1840) in the Opuće Bay (Photo: D. Kulijer).***
Sl. 2: Najdišče in habitat vrste *Notospermus annulatus* ***(Grube, 1840) v zalivu Opuće (Foto: D. Kulijer).***



Fig. 3: *Notospermus annulatus* ***(Grube, 1840) from Opuće (photo: D. Kulijer).***
Sl. 3: *Notospermus annulatus* ***(Grube, 1840) iz lokalitete Opuće (Foto: D. Kulijer).***



Fig. 4: *Notospermus annulatus* ***(Grube, 1840) from Opuće (scale = 5 cm) (Photo: D. Kulijer).***
Sl. 4: *Notospermus annulatus* ***(Grube, 1840) iz lokalitete Opuće (merilo = 5 cm) (Foto: D. Kulijer).***

the Croatian waters. It is characterized by muddy and sandy bottom with rocky intertidal zone. The specimen was collected by hand, photographed and preserved in 96% ethanol. It is deposited in the invertebrate collection of National Museum of Bosnia and Herzegovina (inventory code: INVA 000196). Species identification and status is based on Grube (1840) and Kajihara *et al.* (2022).

RESULTS AND DISCUSSION

A single specimen of *Notospermus annulatus* (Figs. 3 and 4) was found at the depth of approximately 30 cm, on sandy/gravel bottom, under the stone in lower shore intertidal zone, which is a similar habitat to the one reported by Gibson (1995) and Lipej *et al.* (2017) for *N. geniculatus*. The specimen was 93 cm long and approximately 1 cm wide. The coloration varied from dark olive green, blue to dark brown with light rings along the body (Figs. 3 and 4). Rhynchodeum was observed, while caudal cirrus was absent.

Despite the low number of published records, *N. annulatus* is probably more common and widespread in the Mediterranean, and this probably applies to the Adriatic Sea as well. According to Tarman (1961) and Lelo (2012) only one species of the phylum Nemertea, *Prostoma hercegovinense* Tarman, 1961, is known from Bosnia and Herzegovina so *N. annulatus* is only the second species of this phylum known for the country and the first in marine waters. This finding expands the knowledge of the species distribution in the Adriatic Sea and represents valuable contribution to the knowledge of the national marine fauna.

NOTOSPERMUS ANNULATUS (NEMERTEA: LINEIDAE), PRVI ZAPIS O POJAVLJANJU ZA BOSNO IN HERCEGOVINO

Adla KAHRIĆ & *Dalila DELIĆ*
Center for marine and freshwater biology Sharklab ADRIA, Paromlinska 16, 71 000 Sarajevo, Bosnia and Herzegovina
e-mail: adla.k@hotmail.com

Dejan KULIJER
National Museum of Bosnia and Herzegovina, Zmaja od Bosne 3, 71 000 Sarajevo, Bosnia and Herzegovina

POVZETEK

Avtorji predstavljajo prvi zapis o pojavljanju vrste nitkarja Notospermus annulatus *(Grube, 1840) v Bosni in Hercegovini. Dolgo časa je veljal za sinonim vrste* Notospermus geniculatus *(Delle Chiaje, 1822), vendar je na podlagi nedavnih molekularnih filogenetskih raziskav predlagan njen status kot samostojne vrste, kar so avtorji v prispevku upoštevali. Primerek te vrste je bil najden 2. oktobra 2021 v majhnem zalivu pri Opućah na polotoku Klek. Ta najdba prispeva k razumevanju razširjenosti vrste v Jadranskem morju in izpopolnjuje poznavanje slabo poznane morske favne na nacionalnem nivoju. To je prvi zapis o pojavljanju kateregakoli nitkarja v morskih vodah Bosne in Hercegovine.*

Ključne besede: Jadransko morje, Neumski zaliv, razširjenost, morska favna, Sredozemlje

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REPORT OF AN INTERESTING *TRAPANIA* (GASTROPODA: NUDIBRANCHIA: GONIODORIDIDAE) SPECIMEN FROM CENTRAL EASTERN SICILY

Andrea LOMBARDO & Giuliana MARLETTA
Department of Biological, Geological and Environmental Sciences - University of Catania, 95124 Catania, Italy
e-mail: giuliana.marletta@phd.unict.it; andylombardo94@gmail.com

ABSTRACT

The present note reports the finding in the Mediterranean Sea of a particular specimen belonging to the genus Trapania. *Comparing the external morphological data of the found specimen with the relevant literature and sitography, it was observed that this specimen cannot be attributed to any of the hitherto known species of this genus. Future studies that will comprehend a more in-depth investigation of both morphological and anatomical characters, supported by molecular analyses, could allow in the future to do a complete and accurate description of this species.*

Key words: Doridina, Goniodorididae, Ionian Sea, marine Heterobranchia, *Trapania*

SEGNALAZIONE DI UN INTERESSANTE ESEMPLARE DI *TRAPANIA* (GASTROPODA: NUDIBRANCHIA: GONIODORIDIDAE) DALLA SICILIA CENTRO ORIENTALE

SINTESI

La presente nota riporta il ritrovamento nel Mediterraneo di un particolare esemplare appartenente al genere Trapania. *Confrontando i caratteri morfologici esterni dell'esemplare rinvenuto con la letteratura e la sitografia di riferimento, è stato osservato che quest'esemplare non può essere attribuito a nessuna delle specie finora conosciute appartenenti a questo genere. Futuri studi che comprenderanno una più approfondita indagine dei caratteri sia morfologici che anatomici, accompagnati da analisi molecolari, potranno consentire in futuro di effettuare una completa e accurata descrizione di questa specie.*

Parole chiave: Doridina, Goniodorididae, mar Ionio, Heterobranchia marini, *Trapania*

INTRODUCTION

The nudibranch species belonging to the genus *Trapania* Pruvot-Fol, 1931 present a characteristic aspect, which makes them easily distinguishable from other dorids. The body is longitudinally elongated, and the only evidences of the mantle ridge are represented by two pairs of curved lateral processes, the first located laterally to the rhinophores and the second on each side of the gills.

The rhinophores are club shaped and lamellated. The gills are three and can be bipinnate or tripinnate. The oral tentacles are relatively short and round and beneath them, from the anterior edge of the foot, two tentacular eversions originate (Rudman, 1987). Rudman (1987) highlighted that, to diversify and determine the species of this genus, one of the most important features is the external colouration.

Examining the scientific literature (Cervera *et al.*, 2000; Trainito & Doneddu, 2014; Trainito *et al.*, 2018; Doneddu *et al.*, 2020), it appears that currently in the Mediterranean the species belonging to this genus are seven: *Trapania graeffei* (Bergh, 1880); *T. lineata* Haefelfinger, 1960; *T. maculata* Haefelfinger, 1960; *T. orteai* Garcia-Gomez & Cervera in Cervera & Garcia-Gomez, 1989; *T. pallida* Kress, 1968; *T. hispalensis* Cervera & Garcia-Gomez, 1989 and *T. tartanella* (Ihering, 1886). This assemblage of species emerged by the fact that, recently, Doneddu *et al.* (2020) highlighted that all the Mediterranean findings previously attributed to *T. fusca* (Lafont, 1874) [a species until recently considered present in the Mediterranean Sea (Trainito & Doneddu, 2014)], are actually reports of *T. graeffei*. Indeed, these two species were considered as synonyms (e.g. Pruvot-Fol, 1954; Schmekel & Portmann, 1982) or probable synonyms (e.g. Rudman, 1987). Instead, Doneddu *et al.* (2020) have recently re-established the taxonomical validity of *T. graeffei*, considering it as a separate species, different from *T. fusca*. Consequently, according to these authors, *T. fusca* is an Atlantic species exclusively known for its type locality (Arcachon basin, French Atlantic coasts) and thus not present in the Mediterranean.

Recently, during a scuba dive in a site located along the central-eastern coast of Sicily, we encountered a nudibranch specimen belonging to the genus *Trapania*, which presented an external morphology not corresponding to no other species of this genus so far described. Consequently, with the present note, it is documented the finding of an interesting *Trapania* specimen, which if found again in the future, would deserve further morphological-anatomical and genetic investigations.

MATERIAL AND METHODS

The present report was carried out in a site called Scalo Pennisi (37°38′23.2″ N - 15°11′04.6″ E) situated in the hamlet of Santa Tecla (in the municipality of Acireale) located along the central-eastern coast of Sicily (Italy).

The found specimen of *Trapania* was not collected, but it was photographed through an Olympus TG-4 Underwater Camera, during a scuba dive, conducted by the authors between 9–11:30 a.m. on 20th January 2022. The specimen identification was carried out by examining photographs and comparing them with information contained in the relevant literature and sitography (Haefelfinger, 1960; Kress, 1968; Schmekel & Portmann, 1982; Rudman, 1998; Cervera *et al.*, 2000; Gosliner & Fahey, 2008; Trainito & Doneddu, 2014; Doneddu *et al.*, 2020; MolluscaBase, 2022).

RESULTS

On 20th January 2022, in the site of Scalo Pennisi, it was found at 21.7 m of depth (seawater temperature = 15°C) a nudibranch specimen belonging to the genus *Trapania*. The animal (Fig. 1 A-G) presented a greyish general body colouring. On most of the body surface, there were scattered brown dots. These latter were easily visible dorsally, in the space between the rhinophores and the gills and at the base of them. Moreover, these dots were also present on the flanks, on either side of the head and behind the gills. On the body surface there were also rough white longitudinal lines/spots arranged as follows: a characteristic inverted V-shaped pattern that went from each oral tentacle to the antero-dorsal part of the head; some longitudinal spots scattered in the space between the rhinophores, the gills, the flanks, on the dorsal part of the tail and on all body processes. These last presented all (including the point of the tail) distally a yellow-lemon coloration. Rhinophores presented 8-9 lamellae. The specimen presented a body length of 8-9 mm. The animal was observed while climbing on a thallus of *Halopteris filicina* (Grateloup) Kützing. However, in order to improve the photographic output, the specimen was moved on a thallus of *Zonaria tournefortii* (J. V. Lamouroux) Montagne.

DISCUSSION

Through the comparison of the external morphology of our specimen with the other 47 known species of *Trapania* (MolluscaBase, 2022), it was observed that the individual described in the present note does not match to no other species belonging to this genus. Indeed, the presence of

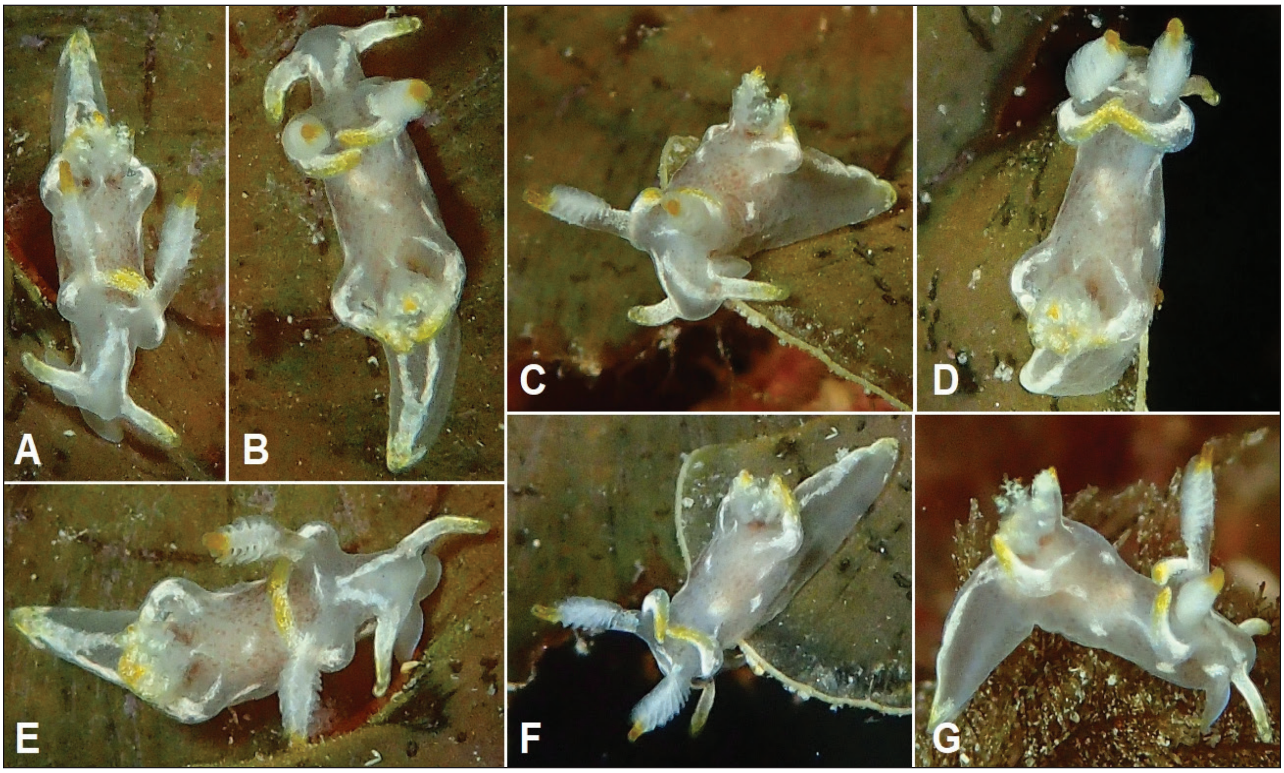


Fig. 1: *Trapania* ***sp. found in Scalo Pennisi (Sicily, Italy). A) anterior view; B) dorsal view; C) left antero-lateral view; D) postero-dorsal view; E) dorso-lateral view during crawling; F) left dorso-lateral view; G) right dorso-lateral view (Photos by A. Lombardo).***

Sl. 1: Primerek vrste iz rodu *Trapania****, najden na lokaliteti Scalo Pennisi (Sicily, Italy). A) pogled od spredaj; B) pogled od zgoraj; C) pogled s sprednje bočne strani; D) pogled zadnjega dela od zgoraj; E) pogled od zgoraj in z boka med plazenjem; F) levi hrbtno-bočni pogled; G) desni hrbtno-bočni pogled (Fotografije: A. Lombardo).***

a particular discontinuous pattern of white lines/spots and of brown dots scattered along some areas of the body, makes this animal not attributable to no other known species belonging to this genus. The unique description, which reflects some of the external features found in our specimen, is that reported by Schmekel and Portmann (1982), for some specimens detected at Ischia (Italy) and identified by them as *T. fusca*: "General body-colour yellowish. The tips of the gills, cerata, oral tentacles and the tip of the tail are bright cadmium yellow. Opaque white dots form a broad diffuse stripe dorsally, which runs from the upper lip to the base of the rhinophores, over the pericard, to the appendages of the gills and to the tail. On each side of the body there is another vague, white, longitudinal stripe. Fine brown pigment covers the surface, wherever the opaque white is absent". Nevertheless, this description does not correspond to the original description of *T. fusca* written by Lafont (1874): "Body brown, speckled with small white dots; anterior tentacles yellow, with brown base; upper tentacles with translucent base, cylindrical apex, greenish-yellow and middle part lamellate with 7 lamellae; branched gills, pale yellow in color". Moreover, as abovementioned, recently Doneddu *et al.* (2020) highlighted that all Mediterranean records of *T. fusca* are actually attributable to *T. graeffei*. However, the specimens found by Schmekel and Portmann (1982) and by us are completely different from *T. graeffei* (they do not present either black blotches or pink nuances). Consequently, it is likely that the specimen here reported, as well as those described by Schmekel and Portmann (1982), are not ascribable to either *T. fusca* or *T. graeffei*, but, on the contrary, might belong to a different taxonomical entity. In our opinion, these individuals could represent a new species that here we limit ourselves to denote as *Trapania* sp., due to the insufficient amount of morphological and anatomical data. Therefore, future studies, which will comprehend a more in-deep investigation of both morphological and anatomical features, supported

by molecular analyses, could allow to perform a complete description of this species. Moreover, continuous monitoring activities in field may increase the knowledge on this group and on the Mediterranean biodiversity.

ACKNOWLEDGEMENTS

We would like to thank two anonymous reviewers, which through their suggestions and criticism, allowed to improve the present manuscript.

ZAPIS O ZANIMIVEM PRIMERKU IZ RODU *TRAPANIA* (GASTROPODA: NUDIBRANCHIA: GONIODORIDIDAE) IZ OSREDNJE VZHODNE SICILIJE

Andrea LOMBARDO & Giuliana MARLETTA
Department of Biological, Geological and Environmental Sciences - University of Catania, 95124 Catania, Italy
e-mail: giuliana.marletta@phd.unict.it; andylombardo94@gmail.com

POVZETEK

Avtorja poročata o najdbi nenavadnega primerka iz rodu Trapania *v Sredozemskem morju. Primerjava zunanjih morfoloških znakov najdenega primerka je pokazala, da je ne moremo uvrstiti v nobeno doslej znano vrsto iz tega rodu. Prihodnje raziskave, ki bodo upoštevale poglobljeno analizo morfoloških in anatomskih znakov in bodo podprte z molekularnimi analizami, bodo omogočile popoln in natančen opis te vrste.*

Ključne besede: Doridina, Goniodorididae, Jonsko morje, morski zaškrgarji, *Trapania*

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STOCK ASSESSMENT, CARTOGRAPHY AND SEXUALITY OF THE WEDGE CLAM *DONAX TRUNCULUS* IN THE GULF OF GABES (TUNISIA)

Abdelkarim DERBALI & Othman JARBOUI
Institut National des Sciences et Technologies de la Mer (INSTM). BP 1035 Sfax 3018, Tunisia
e-mail: derbali10@gmail.com; abdelkarim.derbali@instm.rnrt.tn

ABSTRACT

In Tunisia, the wedge clam Donax trunculus *is one of the most dominant species of the sandy beach macrofauna. Despite its economic value, this target species is still unexploited and there have been no studies focusing on its current status. This study is the first attempt to investigate the stock assessment, spatial distribution, and sexuality of* D. trunculus*. The obtained results revealed that densities ranged from 0 to 278 ind. m^{-2}, and biomass varied between 0 and 444 g m^{-2}. The amount of the latter was equal to 130.1 tons, with high abundance levels reaching over 129.5 million individuals in an area of 4935 hectares. The shell length within the population varied substantially from one locality to another, ranging from 4.8 to 32.7 mm. The overall sex ratio (F:M) was 1:1.52. The species proliferates in Tunisia and is subjected to a congregated demand of markets through regulated fisheries.*

Key words: *Donax trunculus*, stock assessment, cartography, sexuality, Gulf of Gabes, Tunisia

VALUTAZIONE DELLO STOCK, CARTOGRAFIA E SESSUALITÀ DELLA TELLINA *DONAX TRUNCULUS* NEL GOLFO DI GABES (TUNISIA)

SINTESI

In Tunisia, la tellina Donax trunculus è *una delle specie di macrofauna più dominanti delle spiagge sabbiose. Nonostante il suo valore economico, questa specie non è ancora sfruttata e non ci sono studi che si concentrino sullo stato attuale. Il presente studio è il primo tentativo di valutazione dello stock, della distribuzione spaziale e della sessualità di* D. trunculus*. I risultati ottenuti hanno rivelato che le densità variano da 0 a 278 ind. m^{-2},* e la biomassa varia tra 0 e *444 g m^{-2}*. L*a quantità di quest'ultima* è *pari a 130,1 tonnellate, con alti livelli di abbondanza che raggiungono oltre 129,5 milioni di individui in un'area di 4935 ettari. La dimensione delle conchiglie della popolazione varia sostanzialmente da una località all'altra, variando da 4,8 a 32,7 mm. Il rapporto complessivo tra i sessi (F:M)* è *pari a 1:1,52. La specie prolifera in Tunisia ed è sottoposta ad una domanda di mercato attraverso la pesca regolamentata.*

Parole chiave: *Donax trunculus*, valutazione degli stock, cartografia, sessualità, Golfo di Gabes, Tunisia

INTRODUCTION

The wedge clam *Donax trunculus* is an Atlantic-Mediterranean warm-temperate species. It enjoys a wide distribution throughout the Mediterranean and Black Seas, and from North Africa to the northern Atlantic coast of France (Ansell & Bodoy, 1979). This species lives in highly energetic environments on sandy beaches, where it is exposed to tidal rhythms, intense wave action and sediment instability (Brown & McLachlan, 1990; Tlili & Mouneyrac, 2019). The target species is encountered in the 0–2 m depth range in the Mediterranean Sea, and between 0–6 m on the Atlantic coasts, with higher concentrations at depths ranging from 0 to 3 m (Gaspar *et al*., 2002).

D. trunculus is widely distributed along Tunisian coasts. It could acquire an important role in solving the problem of shortage and elevated price of protein source in Tunisia. Moreover, the wedge clam *D. trunculus* could play an important role in the social-economic context, mainly due to the number of fishermen involved in this activity off the Gulf of Gabes. Tunisian coasts extend over long distances and it has become necessary to take a closer look at the exploitation of bivalves inhabiting these areas. To date, shellfish exploitation has focused particularly on the carpet shell clam *Ruditapes decussatus* (Linnaeus, 1758) which, in Tunisia, is heavily harvested from natural populations and represents one of the most important economic products in the country in terms of export.

In areas where the resource exists, the wedge clam *D. trunculus* has often attracted researches for economic interests. Most of the studies have been carried out in Egypt (Kandeel, 2017), Italy (Manca Zeichen *et al*., 2002), Portugal (Gaspar *et al*., 1999), Algeria (Degiovanni & Moueza, 1972; Moueza & Frenkiel-Renault, 1973), Morocco (Lamine *et al*., 2020), Turkey (Colakoglu & Tokac, 2011) and Spain (Ruiz-Azcona *et al*., 1996), particularly focusing on the Mediterranean Sea and North Atlantic populations. These investigations have mainly dealt with bivalve stocks assessment (Charef *el al*., 2011; Pinello *et al*., 2020), growth and reproduction (Ansell & Bodoy, 1979; Deval, 2008; Gaspar *et al*., 1999; Kandeel *et al*., 2018), population structure, and production (Manca Zeichen *et al*., 2002; Colakoglu & Tokac, 2011; Colakoglu, 2014). Several studies on the burrowing behaviour of many species of *Donax* have been conducted by McLachlan & Young (1982), Donn & Els (1990), Ansell *et al*. (1998) and Huz *et al*. (2002). In Tunisia, although there is now an extensive literature on the reproductive cycle and biochemical composition (Boussoufa *et al*., 2011, 2015; Aouini *et al*., 2017, 2018), no studies have been carried out about the spread of the wedge clam *D. trunculus*; it is of interest therefore, to record its current status in an area of extensive shellfish production.

This species could be relevant in terms of its potential for exploitation. At present, there are no artisanal fisheries for *D. trunculus* in the southern coasts of Tunisia. Therefore, this paper represents the first attempt to obtain basic information on the target species by investigating its stock size, geographical distribution, and some biological aspects related to the role of certain abiotic factors.

MATERIAL AND METHODS

Study area

The Gulf of Gabes is located in southern Tunisia and in the southern Mediterranean Sea. Its shoreline extends for 750 km from La Chebba 35°N to the Libyan border (Fig. 1). It has an arid and semiarid Mediterranean climate largely influenced by the area's mild topography and maritime exposure (Chamtouri *et al*., 2008). Both wide and shallow continental shelves are topographically regular. The bottom slightly declines towards the sea and the 60 m depth occurs at 110 km from the coast (Ben Othman, 1973). It is divided into two intertidal zones, soft sand and muddy sand shores (with or without seagrass beds) (Derbali, 2011). The latter are mostly covered by the seagrasses *Cymodocea nodosa* (Ucria) Ascherson and *Zostera noltei* Hornemann. Moreover, the Gulf of Gabes is known for its benthic community and an exceptional bionomy made up of extensive magnoliophytes *Posidonia oceanica* and *C. nodosa* meadows (Ben Mustapha & Hattour, 2013). Their leaves provide suitable substrate for shellfish establishment and growth.

Field sampling and sample processing

Samples were collected during three years (2016–2018) in the coast of the southern part of Tunisia. The study area was roughly divided into fourteen sites with respect to *Donax* occurrence (Fig. 1). Transects were systematically performed in the sampling area during low tides. Replicates were taken every 50 m along transect lines from extreme high water tide to extreme low water tide. Along transects, 4–10 stations were sampled by quadrats (0.25 m^2) using a shovel. Large and small specimens were collected by hand and using a 2 mm mesh sieve, respectively. During the sampling period, seawater temperature and salinity were measured near the bottom immediately after sampling using a multi-parameter kit (Multi 340 i/SET).

Samples of clams were placed in labelled plastic bags and subsequently preserved in a 7% formaldehyde solution. In the laboratory, the material was sorted and washed to remove sediments and debris. Individuals were identified and counted, while shell length (SL = maximum distance along the antero-posterior axis) was measured with a digital caliper to the nearest 0.01 mm and weighed on a toploading digital scales

(precision of 0.001 g) to determine the total weight (TW). The obtained data set was registered and maps were drawn. Moreover, mean densities (ind. m^{-2}) and biomass (g m^{-2}) were obtained per site, and afterward pooled across areas to assess stocks based on the method of kriging using Arc View v. 3.2 software and according to the following equation (Gulland, 1969): Bi = Ni × Ai/ai × 1/Xi where Bi – represents total biomass; Ni – mean abundance of all quadrat samples in each site; Ai – site area surface; ai – quadrat swept area; and Xi – retained proportion. The impact of sites on SL and on densities was estimated using one way ANOVA. Similarities among sites in terms of stock levels were processed by cluster analysis. Similarly, the harmonic Spearman correlation coefficient was applied to identify any significant correlations between density and biomass of clams in each site. The results are presented as a means ± standard error (SE) and the significance level used for the tests was $p < 0.05$.

For biological study, the sexuality of specimens of wedge clam *D. trunculus* was determined by (1) examination of the macroscopic appearance of the gonad and (2) microscopic examination of gametes. The visceral mass was then teased apart, smears of the visceral wall with attached gonad were examined at 100× magnification, and sex of individuals was determined. The sex ratio (expressed as number of females per males; F:M) was also determined. Statistically significant deviations from a balanced sexual proportion of 1:1 were assessed by the χ^2 test, with statistical significance considered at $p < 0.05$ (Zar, 1996).

Results

Habitat and distribution

A total of 300 transects were made from extreme high water tide to extreme low water tide, corresponding to 2198 replicates. Based on the results of this study, *D. trunculus* was encountered throughout the surveyed areas, inhabiting sandy bottoms at depths between 0 and 1 m. Regarding the substratum cover,

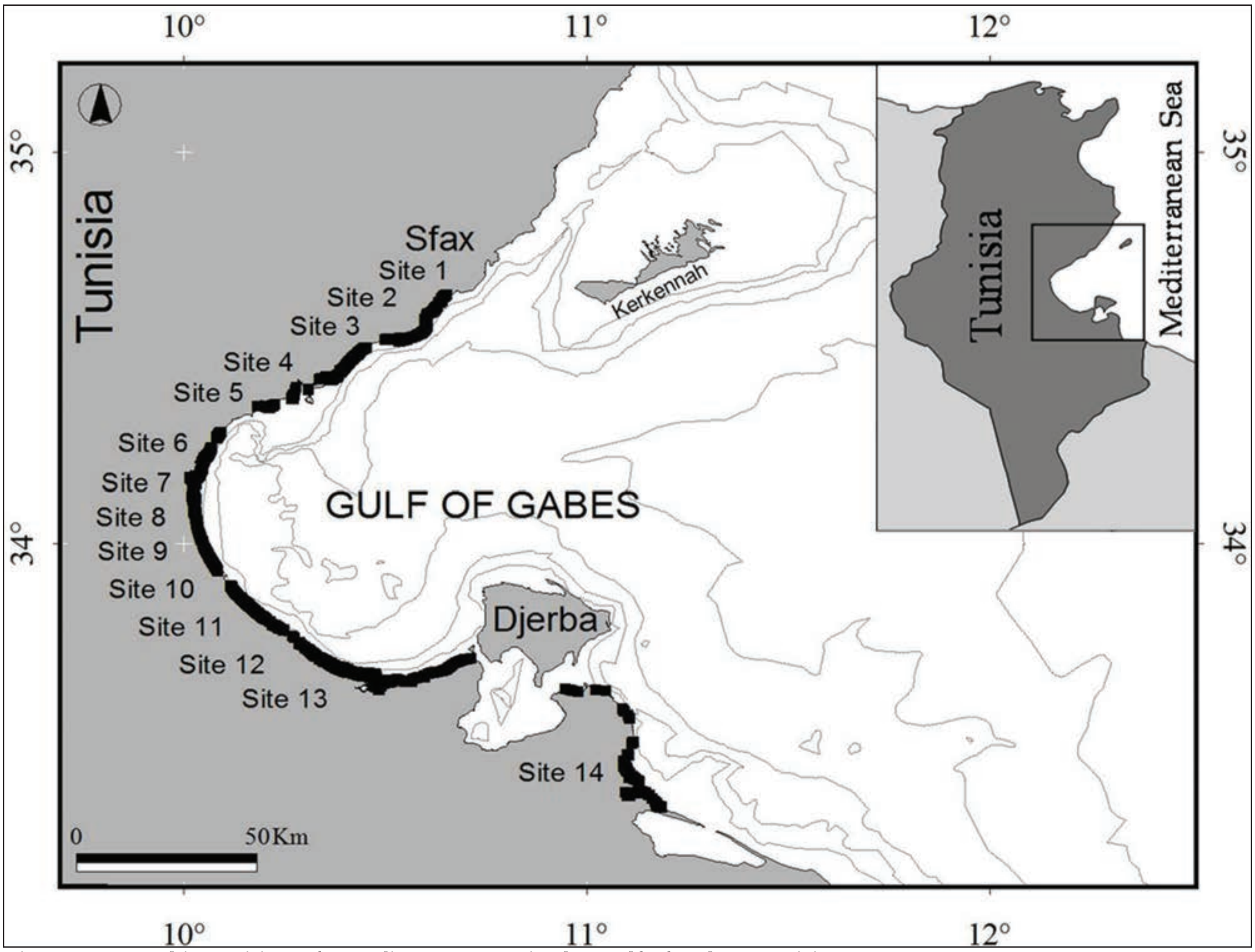


Fig. 1: Geographic position of sampling transects in the Gulf of Gabes (Tunisia).
Sl. 1: Geografski položaj vzorčevalnih transektov v zalivu Gabes (Tunizija).

Tab. 1: Surface area, number of transects and replicates and stock levels (means ± SE) of the wedge clam* Donax trunculus *along the coast of the Gulf of Gabes (Tunisia).

Tab. 1: Površina, število transektov in ponovitev ter ocena staleža (povprečje ± SE) klinaste školjke* Donax trunculus *ob obali zaliva Gabes (Tunizija).

Sites	Surface (ha)	% of all surface	Number of transects	Number of replicates	Means densities (ind. m^{-2}) ± SE	Means biomass (g. m^{-2}) ± SE
Site 1	265	5.37	11	62	0.32 ± 0.13	0.65 ± 0.27
Site 2	146	2.96	12	50	4.64 ± 0.79	10.46 ± 1.78
Site 3	379	7.68	16	82	1.46 ± 0.46	2.62 ± 0.89
Site 4	87	1.76	8	72	0.06 ± 0.01	0.23 ± 0.04
Site 5	395	8,01	28	226	0.23 ± 0.18	0.20 ± 0.17
Site 6	202	4.09	31	168	2.67 ± 1.85	4.84 ± 3.48
Site 7	106	2.15	40	112	14.64 ± 4.24	26.79 ± 7.66
Site 8	148	3.00	20	66	6.18 ± 2.78	9.72 ± 4.75
Site 9	40	0.81	9	50	21.68 ± 11.12	27.35 ± 17.62
Site 10	241	4.88	23	134	8.12 ± 4.63	2.74 ± 1.02
Site 11	595	12.06	11	68	4.41 ± 2.20	1.63 ± 0.57
Site 12	547	11.08	19	290	0.74 ± 0.20	0.71 ± 0.20
Site 13	179	3.63	27	552	1.27 ± 0.31	0.94 ± 0.23
Site 14	1605	32.52	45	266	0.23 ± 0.20	0.05 ± 0.04
Total	4935	100	300	2198	2.89 ± 0.49	3.57 ± 0.67

almost all of the study area hosting the highest population densities (sites 2, 3, and 6 to 13) was dominated by the seagrass *C. nodosa,* and the substrates consisted predominantly of very fine sand. In some areas, *D. trunculus* was also found loose on soft sand. During the sampling operations, the highest and lowest temperature values were recorded in July (27 °C) and in February (12 °C), respectively. Salinity measurements showed an annual fluctuation between 30 in winter and 48 in summer.

In this study, mean stock levels for each site are presented in Table 1. The distribution of *D. trunculus* revealed a discrepancy between the northern, middle and southern gulf shores. The central part was more populated and included two areas (sites 7 and 9) of high clam densities and biomass (Figs. 2 & 3). In these sites, the density per station reached 278 ind.m^2 and biomass recorded remarkable levels of over 444 g m^{-2}. Overall, significant differences in *D. trunculus* distribution among all sites were shown. Density ranged from 0 to 278 ind. m^{-2} and biomass between 0 and 444 g. m^{-2} (Fig. 2 & 3). Both K–S and Levene's tests revealed significant statistical differences in clam abundances ($p < 0.05$). In the same way, pairwise comparisons between biomass values also indicated that obtained data for all production sites were significantly different ($p < 0.05$).

Abundance and biomass

The total biomass was estimated to be 130.1 ± 48.6 tons of total fresh weight, with a mean biomass around 3.6 ± 0.7 g m^{-2} and a total abundance reaching over 129.5 ± 54.1 million individuals. The mean density of the quadrats was equal to 2.9 ± 0.5 ind. m^{-2}. Overall, 1594 individuals were collected from all studied sites (4935 hectares). A layout of significant variation in stock levels among colonised areas is set out in Figure 4. In terms of biomass, there were significant differences among sampling sites ($p < 0.05$) with the exception of site 1 with respect to sites 5 and 14, and site 3 with respect to site 9 ($p > 0.05$). As for biomass, significant variations in total abundances were recorded among sites ($p < 0.05$), with the exception of site 1 with respect to site 5, and sites 8, 9, and 12 with

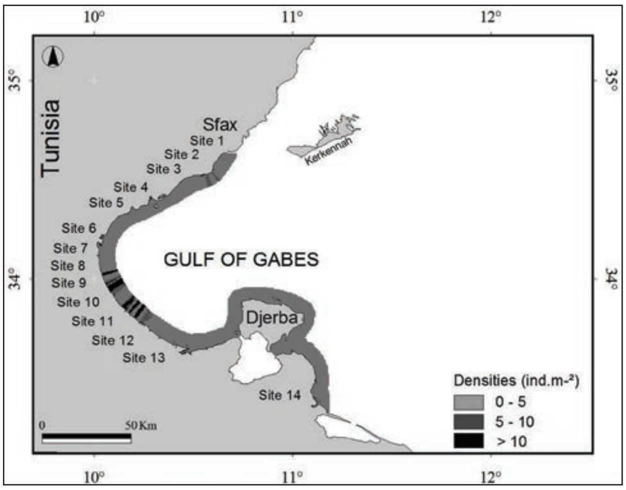


Fig. 2: Spatial distribution of densities of *Donax trunculus* ***in the littoral zone of the Gulf of Gabes (Tunisia).***
Sl. 2: Prostorska porazdelitev gostote klinaste školjke (*Donax trunculus****) v obalnem območju zaliva Gabes (Tunizija).***

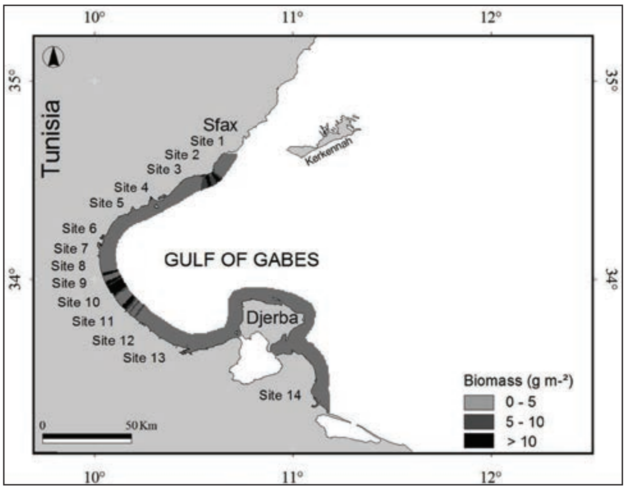


Fig. 3: Spatial distribution of biomass of *Donax trunculus* ***in the littoral zone of the Gulf of Gabes (Tunisia).***
Sl. 3: Prostorska porazdelitev biomase klinaste školjke (*Donax trunculus****) v obrežnem pasu zaliva Gabes (Tunizija).***

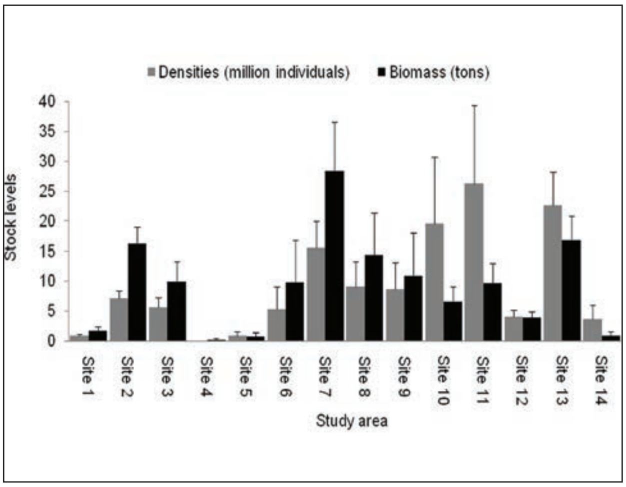


Fig. 4. Stock levels of *Donax trunculus* ***in the colonised zones and their standard error (± SE) along the coast of the Gulf of Gabes (Tunisia).***
Sl. 4: Ocena staleža klinaste školjke (*Donax trunculus****) na območjih pojavljanja in standardna napaka (± SE) ob obali zaliva Gabes (Tunizija).***

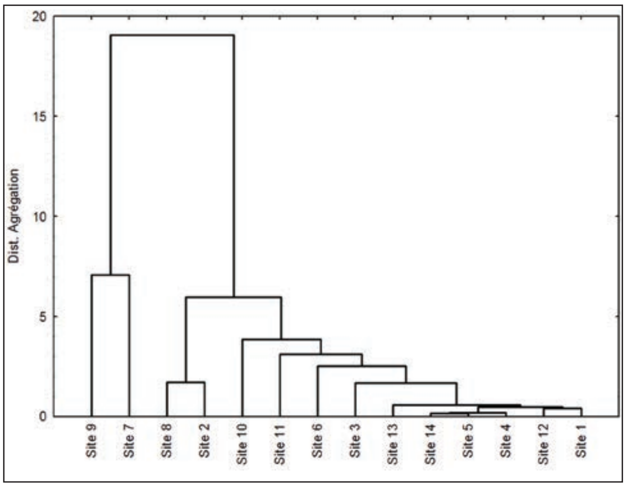


Fig. 5: Similarity dendrograms of colonised zones of *Donax trunculus* ***(average group) along the coast of the Gulf of Gabes (Tunisia).***
Sl. 5: Podobnostni dendrogrami klinaste školjke (*Donax trunculus****) na območjih pojavljanja območjih ob obali zaliva Gabes (Tunizija).***

respect to site 14 ($p > 0.05$). Additionally, through cluster analysis of sites (group average) applied to compare similarities between sites, a principal group was defined from among all sites (Fig. 5). Similarity tests showed that the aforesaid group and sites 7 and 9 were significantly different (global R superior to 0.87; $p < 0.05$). This was generally due to clam stocks being most abundant in sites 7 and 9 with respect to the rest of the sampling area.

Size structure

The size in terms of shell length of the *D. trunculus* collected over the sampling period ranged broadly from 4.8 to 32.7 mm SL. One peak was apparent, corresponding to individuals of 25 mm SL (Fig. 6). The majority of *D. trunculus* population was assigned to size classes 11–29 mm SL, which represented 97.2% of the total samples. Only 0.01% of the sampled specimens were

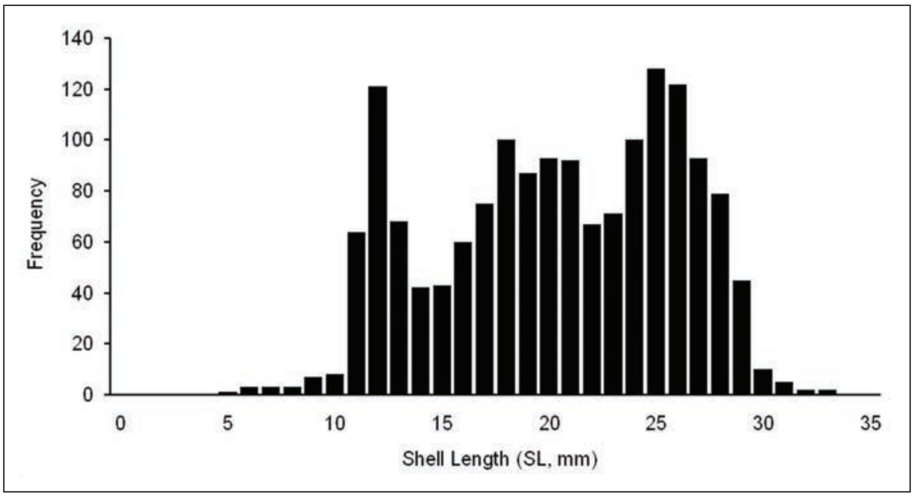


Fig. 6: Length–frequency distribution of *Donax trunculus* ***along the coast of the Gulf of Gabes (Tunisia).***
Sl. 6: Velikostna porazdelitev klinaste školjke (*Donax trunculus****) vzdolž obale zaliva Gabes (Tunizija).***

larger than 30 mm SL, collected in sites 2 and 7, situated in the northern and central parts of the study area. This could mainly be attributed to natural mortality caused by pollution and increased temperatures in summer. Unfortunately, the mortality rate was not estimated.

The mean length was 20.42 ± 0.14 mm SL in this study. Statistical analysis revealed there was a significant difference ($p < 0.001$) among mean shell lengths recorded in individual studied sites. Mean sizes ranged from 9.36 ± 0.8 mm in site 14 to 26.80 ± 0.31 mm in site 2 (Tab. 1), and the sizes of the individuals appearing greatly influenced by location. Significant variations were observed between mean shell lengths of specimens collected from sites 1 to 9 when compared to those from other sites (10–14, $p < 0.001$). Furthermore, the shell length-weight relationship for overall data (1594 individuals) showed positive correlation ($R^2 = 0.9695$; $p < 0.001$, Fig. 7)

Sex ratio

Of the specimens analysed, 794 were males (49.8%), 522 females (32.7%), and 278 of indeterminate sex (17.4%). The wedge clam specimens presented a broad size range, both in term of shell length (4.8–32.7 mm) and total weight (0.03–4.25 g). The overall sex ratio (F:M = 1:1.52) was significantly divergent from parity (F:M = 1:1; χ^2-test, $p < 0.001$).

DISCUSSION

The current study reports for the first time the spread of the wedge clam *D. trunculus* over the largest shellfish production area in the south of Tunisia by investigating the stock levels, population distribution and some biological aspects. Maps show a scattered distribution pattern both in terms of density and biomass. The wedge clam has colonised areas with a depth range of 0–1 m, which supports an important stock representing 71.7 tons of total fresh weight and high abundance levels reaching over 11.7 million individuals. Generally, this study is aimed at ascertaining whether the stock of a given species is large enough to warrant the beginning or continuation of the management of its stocks. On comparison, data on biomass assessment and distribution are insufficient. This stock is much larger than that recorded in the Gulf of Tunis (3 tons) located in the north of Tunisia (Charef *et al.*, 2011). Our sampling operations showed that the variance within and among sites was large, and standard errors (SE) of densities and biomass were correspondingly wide. A gradient similar to this can be observed in another clam species (*Mactra stultorum*), with about 113 tons estimated in the same study area (unpublished data).

Maps of stocks revealed the fluctuation of *D. trunculus* habitats in the prospected area. As a result, the *D. trunculus* stocks varied considerably across the sites. It seems mainly that clam populations have been strongly influenced by various factors related to the study area (e.g., physicochemical, edaphic and hydrological) (Derbali, 2011). During our sampling operations, the hydrodynamic conditions were found to be similar within the sampling area and it might be assumed that relative *D. trunculus* stocks were influenced by other environmental parameters such as sediment type, organic matter content, the burrowing behaviour of bivalve species and their subsequent

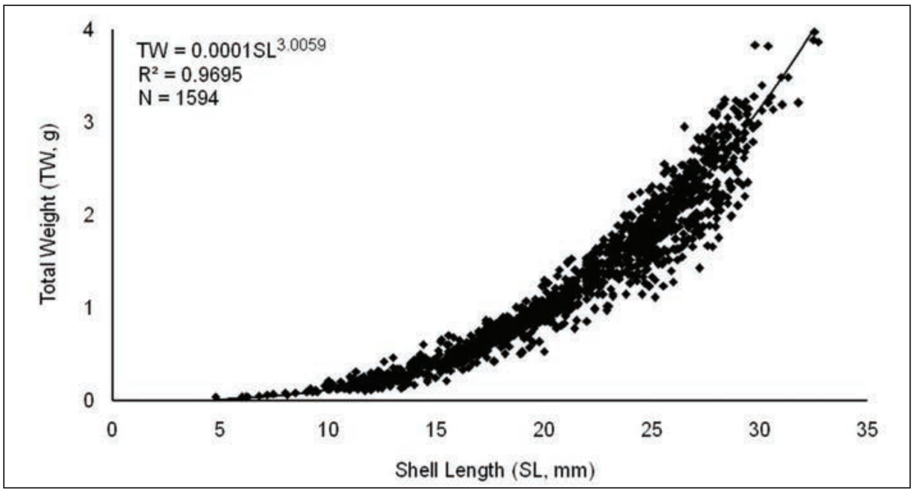


Fig. 7: Relationship between shell length (SL) and total weight (TW) of Donax trunculus along the coast of the Gulf of Gabes (Tunisia).
Sl. 7: Odnos med dolžino lupine (SL) in celotno težo (TW) klinaste školjke** (Donax trunculus)* ***vzdolž obale zaliva Gabes (Tunizija).

strategies to counter dislodgement and avoid predation (Derbali, 2011). In fact, some interesting connections between environmental conditions and bivalve lifestyles were detected in this study area, with the elevated water temperatures and phytoplankton levels possibly promoting rapid growth rates in many local bivalve species. Due to high water temperature levels (12–27 °C) and shallowness, the salinity remains fairly stable and high throughout the year, peaking during summer (47–48) and often in winter (28–30). This indicates that *D. trunculus* has a high salinity tolerance. The maximum value recorded from the present study area (48) was much higher than that recorded along the north Tunisian coast, where salinity ranged between 34 and 39 (Boussoufa *et al.*, 2011). These authors demonstrated that *D. trunculus* tolerated a hypo- to hyperhaline salinity range and the fluctuations observed did not have any significant effect on the wedge clam reproduction. Similar results have been reported for other bivalve species, including the cockle *Cerastoderma glaucum* and the pearl oyster *Pinctada radiata* (Derbali, 2011). Conversely, Neuberger-Cywiak *et al.* (1990) argued that low population densities of *D. trunculus* in the Mediterranean coasts of Israel were caused by the low temperature and reduced salinity of the surface waters due to heavy rains.

Overall, in these conditions, *D. trunculus* can be the most dominant at a depth range of 0–1 m. In the same way, Manca Zeichen *et al.* (2002) mentioned that the target species proved to be the dominant species of the macrofauna community in the south Adriatic coast (Italy) at 0–2 m depth ranges, beyond which the species disappeared abruptly, giving way to a progressive dominance of *D. semistriatus*. Similarly, Colakoglu (2020) reported that *D. trunculus* was found at depth ranges from 0 to 2 m in Marmara Sea (Turkey).

Other additional mechanisms affecting *D. trunculus* populations include soft bottoms and nutrients. Indeed, mud sandy substrates (sites 1, 4, 5 and 14) prevent the species proliferation, as evidenced by the small densities recorded in these areas. *D. trunculus* requires a particular type of sediment in its habitat. The distribution of the wedge clam might be a result of substratum selectivity. *Donax* species are highly selective of substratum (Ansell & Trevallion, 1969; Degiovanni & Moueza, 1972), but the influence of other environmental factors on shellfish aggregations is also interesting. *D. trunculus* was harvested from areas in which the seagrass *C. nodosa* covered almost all the colonised habitat (sites 2 and 3, and 6–13). It seems that the scattered distribution of *D. trunculus* was considerably correlated with the seagrass beds, suggesting that these sites provide good conditions for the proliferation of wedge clam. It can thus be deduced that this seagrass species improves the nutritive resources and dissolved oxygen levels. Other parameters such as light and tides can also have an influence on bivalves' lifestyle (Drummond *et al.*, 2006; da Costa *et al.*, 2013). In fact, *D. trunculus* has a wedge-shaped shell which seems to be an adaptation for rapid burrowing and for migrating between tide levels (Stanley, 1970). These properties were confirmed by the omnipresence of the wedge clam in the most colonised sites corresponding to energy beaches (Fig. 4). Nevertheless, the low abundance of the wedge clam recorded in sites 1 to 6 in the northern

and central parts of the study area is attributable to the continuous inputs of the industrial waste (Bejaoui *et al*., 2004).

Regarding shellfish richness, the colonised area constitutes an ecosystem with macrofaunal diversity with bivalve and gastropod species (Derbali, 2011). This faunal group, which includes *Donax trunculus*, feeds by filtering nutrients from the water column. The spatial distribution of shellfish colonisation might be linked to ecological and physiological properties of the encountered bivalves, namely their affinity for substrate type. The high diversity of shellfish species is particularly interesting when the relative organic matter content and depth range (0–1 m) are considered. In fact, these factors can provide ecological conditions that are able to maintain highly diverse reef communities in the present studied area. Extensive works have confirmed the correlation between community structure and the primary production (Menge & Olson, 1990; El Lakhrach *et al*., 2012). Indeed, density and biomass of filter-feeders was proved to be correlated with both intertidal productivity and nearshore primary productivity (Menge & Olson, 1990; Agirbas *et al*., 2014). These findings may explain the prevalence of shellfish species in these particular grounds. In addition, this corroborates the importance of environmental conditions in controlling shellfish abundance. As such, physical parameters, namely surface and depth, might play a major role in affecting distribution patterns and aggregation densities of shellfish in shallow waters (Neuberger-Cywiak *et al*., 1990; Tlili & Mouneyrac, 2019).

In our study, the wedge clam *D. trunuclus* exhibited characteristics similar to those reported for other bivalve species. The condition factor estimated from the length-weight relationship can serve as an indicator of the "well-being" of a given species and an indicator of food abundance for the species in a given area or time (Mzighani, 2005). In bivalve species, several environmental factors are known to influence shell morphology and relative proportions, such as depth (Claxton *et al*., 1998), shore and tidal levels (Franz, 1993), wave exposure (Akester & Martel, 2000), type of bottom (Claxton *et al*., 1998) and substratum type (Newell & Hidu, 1982). Tlig-Zouari *et al*. (2010) and Derbali *et al*. (2011, 2012) from Tunisia noticed that these aspects varied within bivalve species in localities with different environmental conditions. In fact, the size ranges of some bivalve species are highly variable among studies, complicating comparisons from different geographical areas. In the present study, the shell length ranged between 4.8 and 32.7 mm SL, with the mean length at 20.42 mm SL. The majority of clams belonged to size classes (11–29 mm), with only specimens of 25 mm SL standing out for numerosity. In fact, the length–frequency distribution was almost normal. We can speculate that this size structure might be a result of the nonexploitation of the natural populations of *D. trunculus*. One can assume that the growth, development and survival of bivalves are generally conditioned by physical and chemical parameters. This conclusion is the same as that given by Carlier *et al*. (2007), Le Pape *et al*. (2007) and Strachan (2010) in relation to the bivalve species from the northwestern Mediterranean, the Bay of Biscay (France) and the North Sea (UK), respectively.

The sex ratio of the wedge clam *D. trunculus* (F:M = 1:1.52) was significantly divergent from parity (1:1), with males outnumbering females. On comparison, Boussoufa *et al*. (2015) came to the same conclusion for the clam *D. trunculus* from the Bay of Tunis (F:M = 1:1.41). Our result is also in agreement with those reported for *D. trunculus* populations from Turkey (Deval, 2009), Egypt (Kandeel *et al*., 2018) and Portugal (Gaspar *et al.,* 1999). Additionally, previous studies reported that males of the wedge clam generally make up a slightly higher share but they do not show a statistically significant difference from parity (1:1) (Lucas, 1965; Badino & Marchionni, 1972; Moueza & Frenkiel-Renault, 1973). Our findings are in accordance with those of Derbali *et al*. (2021) for the surf clam *Mactra stultorum* in southern Tunisian waters (F:M = 1:1.37), Chung *et al*. (1988) for *Mactra veneriformis* in Korea, and Kandeel (1992) for the clam *Polititapes aureus* from Lake Timsah in Egypt (F:M = 1:1.15).

The increased proportion of males compared to females is probably due to differential growth or differential mortality as a probable result of spawning effort.

To conclude: the wedge clam *Donax trunculus* is a native Tunisian species widely distributed along southern Tunisian coasts. Due to its economic value, it could represent a valuable species for commercial exploitation in Tunisia. This study gives more information about its stock in the most extensive area of shellfish production. The data may help to determine future quantitative changes and trends in southern Tunisian waters, which are exposed to various environmental factors and human activities. Future studies are needed to obtain data on population dynamics.

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OCENA STALEŽA, KARTOGRAFIJA IN SPOLNOST KLINASTE ŠKOLJKE *DONAX TRUNCULUS* V GABEŠKEM ZALIVU (TUNIZIJA)

Abdelkarim DERBALI & *Othman JARBOUI*
Institut National des Sciences et Technologies de la Mer (INSTM). BP 1035 Sfax 3018, Tunisia
e-mail: derbali10@gmail.com; abdelkarim.derbali@instm.rnrt.tn

POVZETEK

*Klinasta školjka (*Donax trunculus*) je ena izmed prevladujočih vrst makrofavne peščenega dna. Kljub svoji gospodarski vrednosti je ta ciljna vrsta še vedno neizkoriščena in doslej ni bilo opravljenih nobenih študij, ki bi se osredotočale na njen trenutni status. Ta študija je prvi poskus raziskovanja ocene staleža, prostorske porazdelitve in spolnosti vrste* D. trunculus. *Dobljeni rezultati so pokazali, da so njene gostote med 0 in 278 os. m*$^{-2}$, njena biomasa pa med 0 in 444 g m^{-2}. Na območju velikem 4935 hektarjev je bila biomasa ocenjena na 130,1 tone, število osebkov pa na 129*,5 milijona. Dolžina lupine v populaciji se je od lokacije do lokacije močno razlikovala in se je gibala od 4,8 do 32,7 mm. Delež med spoloma (samice: samci) je znašal 1:1.52. Vrsta se razmnožuje v Tuniziji in je zaradi reguliranega ribolova izpostavljena povpraševanju na trgu.*

Ključne besede: *Donax trunculus*, ocena staleža, kartografija, spolnost, gabeški zaliv, Tunizija

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LENGTH-WEIGHT RELATIONSHIPS AND DENSITY OF BIVALVE SPECIES IN THE SHELLFISH PRODUCTION AREA OF ZARZIS (TUNISIA, CENTRAL MEDITERRANEAN SEA)

Abdelkarim DERBALI, Aymen HADJ TAIEB & Othman JARBOUI
Institut National des Sciences et Technologies de la Mer (INSTM). BP 1035 Sfax 3018, Tunisia
e-mail: derbali10@gmail.com; abdelkarim.derbali@instm.rnrt.tn

ABSTRACT

*The present work reports length-weight relationships (LWRs) for the most common and abundant bivalve species found in coastal areas of Zarzis (southern Tunisia). Systematic surveys were carried out during 2018 on soft bottom in the littoral zone down to 1 m depth. This study provides the first results about LWRs and the density levels of 6 species (*Ruditapes decussatus, Polititapes aureus, Moerella pulchella, Cerastoderma glaucum, Mactra stultorum *and* Loripes orbiculatus*) distributed among five families. A stock size assessment of these target species revealed abundance values ranging from 0.47 to 6.10 indiv. m*$^{-2}$, and biomass values from 1.83 to 10.34 g m^{-2}. *The results showed negative growth in five species and isometric growth in one species. The data presented herein are essential for the management and conservation for these species.*

Key words: Mollusca, bivalvia, Length-weight relationship, Allometric growth, Zarzis coast, Tunisia

RAPPORTO LUNGHEZZA-PESO E DENSITÀ DEI BIVALVI NELLA ZONA DI PRODUZIONE DI MOLLUSCHI DI ZARZIS (TUNISIA, MARE MEDITERRANEO CENTRALE)

SINTESI

*L'articolo riporta le relazioni lunghezza-peso (LWR) per le specie di bivalvi più comuni e abbondanti trovate nelle aree costiere di Zarzis (Tunisia meridionale). Indagini sistematiche sono state effettuate durante il 2018 su fondi molli nella zona litorale fino a 1 m di profondità. Lo studio fornisce i primi risultati sulle LWR e i livelli di densità di 6 specie (*Ruditapes decussatus, Polititapes aureus, Moerella pulchella, Cerastoderma glaucum, Mactra stultorum e Loripes orbiculatus*) distribuite in cinque famiglie. Una valutazione delle dimensioni dello stock di queste specie bersaglio ha rivelato valori di abbondanza che vanno da 0,47 a 6,10 indiv. m*$^{-2}$, e valori di b*iomassa da 1,83 a 10,34 g m*$^{-2}$. I *risultati hanno evidenziato una crescita negativa in cinque specie e una crescita isometrica in una specie. I dati qui presentati sono essenziali per la gestione e la conservazione di queste specie*.

Parole chiave: Mollusca, bivalvia, rapporto lunghezza-peso, crescita allometrica, costa di Zarzis, Tunisia

INTRODUCTION

The length-weight relationships (LWRs) in marine species is of a great use in fisheries biology for converting length measures into weight and ascertaining the growth characteristics related to those variables (Anderson & Gutreuter, 1983). An empirical relationship like LWR is an important piece of information in studying marine organisms. For instance, LWR allows predictions of weight from length (Pauly, 1993).

Bivalve shell growth and shape are influenced by abiotic (exogenous/environmental) and biotic (endogenous/physiological) factors. Shell morphology and relative proportions of many bivalve species are known to be affected by environmental factors, such as latitude (Beukema & Meehan, 1985), depth (Gaspar *et al*., 2002; Derbali, 2011; Derbali *et al*., 2011), currents and water turbulence (Fuiman *et al*., 1999; Hinch & Bailey, 1988), and type of sediment (Claxton *et al*., 1998; Derbali *et al*., 2009a & b). Gaspar *et al*. (2002) have also reported that burrowing behaviour, ability and efficiency also affect the relative growth of bivalve species. In Tunisia, there have been many investigations documented on bivalve species (Tlig-Zouari *et al*., 2010; Bellaaj-Zouari *et al*., 2011; Derbali *et al*., 2018). Nonetheless, the data available on morphometric relationships and stock assessment of shellfish species are very limited. The present study is the first attempt to obtain basic information by investigating the length-weight relationships and densities levels of the most abundant bivalve species harvested along the coasts of Zarzis (southern Tunisia). Studies concerning shell morphometric relationships of the species are underpinned by basic knowledge in different fields of environmental research. Such data are valuable for establishing a monitoring and management system and can be a useful reference for studies of marine invertebrates.

MATERIAL AND METHODS

Sampling protocol and operations

Systematic surveys were carried out from February to October 2018 within the 100 km Zarzis coastal part located in south Tunisia (Fig. 1). Transects were systematically set up every 600 m in the littoral zone during low tides (up to 1 m depth). Bivalve species were collected every 50 m along each transect line from the upper limit of the tide's influence to the low water mark. Along the transects, 4 to 10 sampling stations were marked. In each one, two replicates were taken from the quadrats (0.25 m²) using a shovel. Large specimens were collected by hand and small ones using a 2 mm mesh sieve.

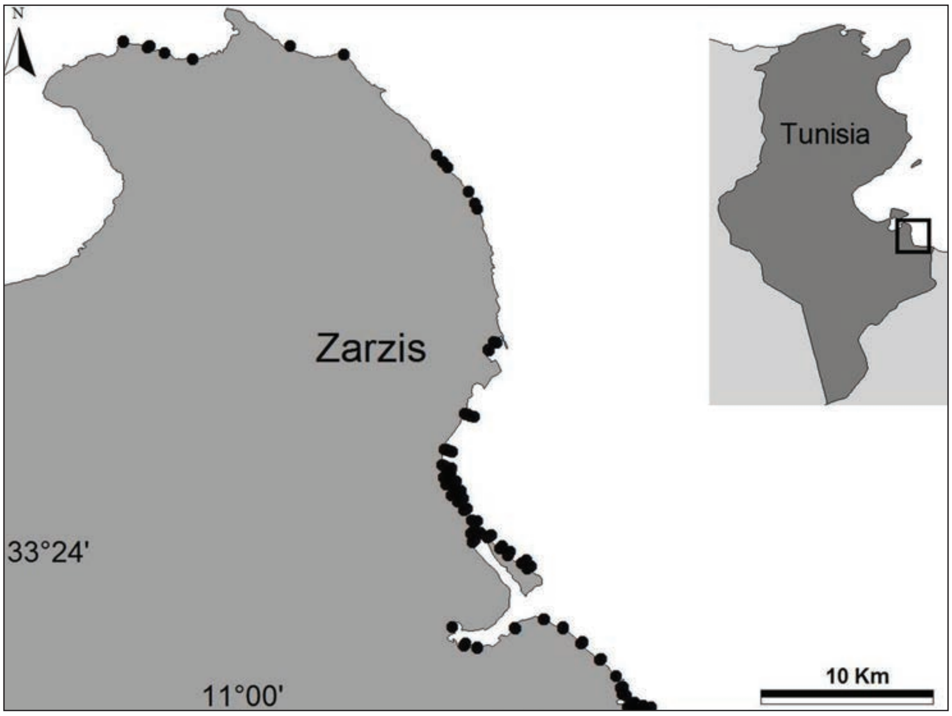


Fig. 1: Map of the study area, indicating the sampling location (Zarzis, Tunisia).
Sl. 1: Zemljevid obravnavanega območja z navedbo lokalitete vzorčenja (Zarzis, Tunizija).

Tab. 1: Descriptive statistics and morphometric relationship parameters for 6 bivalve species from the Zarzis coast (N = number of individuals; L = shell length (mm); W = total fresh weight (g); S.D. = standard deviation; S.E. = standard error; (*) = P < 0.001).

Tab. 1: Opisna statistika in parametri morfometričnega razmerja za 6 vrst školjk z obale Zarzis (N = število osebkov; L = dolžina lupine (mm); W = skupna sveža teža (g); S.D. = standardni odklon; S.E. = standardna napaka; (*) = P < 0,001).

Species	N	Lmean ± S.D (Lmin –Lmax)	Wmean ± S.D (Wmin – Wmax)	Allometric equation	Determin. coefficient (r^2)	S.E. of b	Relationship (t-test)
Family Veneridae							
Ruditapes decussatus	50	26.45 ± 15.00 (3.2 – 54.85)	7.05 ± 7.55 (0.01 – 32.28)	Log W = -3.378 + 2.7942 Log L	0.996 *	0.020	negative allometry
Polititapes aureus	282	22.57 ± 8.11 (3.25 – 35.85)	2.44 ± 1.7 (0.003 – 9.57)	Log W = -3.3709 + 2.6877 Log L	0.9186 *	0.048	negative allometry
Family Tellinidae							
Moerella pulchella	101	6.27 ± 1.54 (2.90 – 17.20)	0.04 ± 0.04 (0.01 – 0.38)	Log W = -2.9425 + 1.8686 Log L	0.8266 *	0.086	negative allometry
Family Cardiidae							
Cerastoderma glaucum	452	15.89 ± 8.29 (1.50 – 35.10)	2.39 ± 2.70 (0.001 – 16.50)	Log W = -3.4484 + 2.9622 Log L	0.9708 *	0.024	isometric
Family Mactridae							
Mactra stultorum	31	26.91 ± 8.13 (6.6 – 37)	3.94 ± 2.70 (0.1 – 8.59)	Log W = -3.3433 + 2.6823 Log L	0.9112 *	0.156	negative allometry
Family Lucinidae							
Loripes orbiculatus	344	10.00 ± 3.06 (3.00 – 16.55)	0.34 ± 0.27 (0.006 – 1.37)	Log W = -3.3969 + 2.8127 Log L	0.89 *	0.053	negative allometry

During each sampling period, seawater temperature and salinity were measured near the bottom immediately after sampling using a multi-parameter kit (Multi 340 i/SET). After sampling, the materials were put in labelled plastic bags, subsequently preserved in a 7% formaldehyde solution to be used as material for data analysis.

Data analysis

In the laboratory, the preserved samples were sorted and washed to remove all adhering organisms and other debris. Specimens were identified and counted. The measurement of the bivalve shell length (maximum distance along the anteroposterior axis, L) was made to the nearest 0.01 mm, using a digital caliper. The total fresh weight (including intra-valves water, W) was measured using a toploading digital balance (precision of 0.001 g). After identification to the species level, data were pooled at sampling sites to obtain mean densities (indiv. m^{-2}) and mean biomass (g m^{-2}). Mean densities of bivalve species recorded in the study area were compared using one-way analysis of variance (ANOVA). The results are presented as means ± standard error (SE) and the significance level used in the tests was $p < 0.05$. In addition, the Spearman's rank correlation coefficient was applied to identify significant correlations between bivalves' density and biomass.

For each bivalve species, the LWRs were estimated using the equation:

$$W = a\,L^b \qquad (1)$$

and its linear transformation:

$$\text{Log } W = \text{Log } a + b \text{ Log } L \qquad (2)$$

where W = total fresh weight; L = length; a = intercept (initial growth coefficient); b = slope (relative growth rate of variables). Besides, the LWRs were determined with a 95% confidence limit of b and the significance level of r^2. The growth type was determined using the t-test, which investigated whether slope b was significantly different from the theoretical value 3, with a confidence level of ± 95% (α = 0.05) (Zar, 2010). The statistical package used was STATISTICA v. 6.0.

RESULTS

Occurrence and abundance

During the studied period, 45 transects were made from the high tide point to the extreme low tide point, which corresponded to 266 sampling stations. A total of 1260 specimens were collected, belonging to 6 bivalve species distributed among 5 families (Tab.e

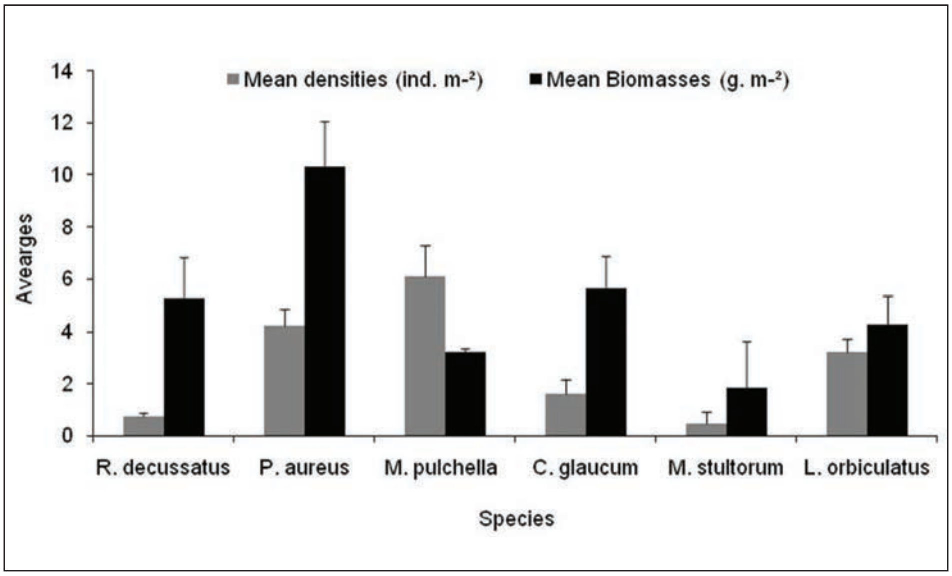


Fig. 2: Density levels of the most abundant bivalve species along the Zarzis coast (south Tunisia) and their standard errors (± SE).
Sl. 2: Gostote najbolj razširjenih vrst školjk vzdolž obale Zarzis (južna Tunizija) in njihove standardne napake (± SE).

1). In terms of numbers of individuals, the most abundant families were the Cardidae (35.88%), the Lucinidae (27.30%) and the Veneridae (26.35%); the least abundant were the Tellinidae and the Mactridae with percentages not exceeding 9%. The target bivalve species were encountered in various substratum types, such as muddy-sandy bottom patchily covered by meadows of *Zostera noltii* or *Cymodocea nodosa* or by mixed vegetation consisting of these two marine seagrasses.

The sample size ranged from 31 individuals, e.g., in the surf clam *Mactra stultorum* (Linnaeus, 1758), to 452 individuals, e.g., in the cockle *Cerastoderma glaucum* (Bruguière, 1789). The assessment of the stock size of these target species across quadrats yielded density values ranging from 0.47 to 6.10 indiv. m^{-2}, with biomass values varying from 1.83 to 10.34 g m^{-2} (Fig. 2). The most numerous species were *M. pulchella* (6.1 indiv. m^{-2}), *P. aureus* (4.24 indiv. m^{-2}) and *L. orbiculatus* (3.22 indiv. m^{-2}). On the other hand, no significant variations occurred between mean values of *R. decussatus*, *C. glaucum* and *M. stultorum* (Fig. 2). This was due to fewer individuals being collected over the period of sampling.

In term of biomass, three species, *P. aureus*, *C. glaucum* and *R. decussatus*, maintained high level values (over 10.34 g m^{-2}, 5.64 g m^{-2} and 5.3 g m^{-2}, respectively). Mean biomass showed significant variations of abundance ($p < 0.05$) between species, with the mean value for *P. aureus* higher ($p < 0.05$) than those of the remaining species. A Spearman's correlation comparison indicated a strong positive correlation (> 0.9) between density and biomass for each species. The present study area has both a qualitative and quantitative importance because all the studied species together accounting for more than 491 tons. The highest temperature values were recorded in July (28°C), the lowest values in February (11°C). Salinity measurements showed an annual fluctuation between 32‰ in winter and 47‰ in summer.

Length-weight relationships

The results obtained for the length-weight relationships, along with some sample descriptive statistics are given in Table 1. The data are not representative of a particular season and were not collected during a specific period of the year. These parameters should therefore only be considered as mean annual values. In addition, the results revealed that in all encountered bivalve species determination coefficients (r^2) were high in length-weight relationships and regressions were all highly significant ($p < 0.001$). The *b* value of the studied samples varied between 1.86 and 2.96. For the 6 species studied, the LWRs indicated a clear prevalence of negative growth (5 species, *b* values = 1.86–2.81) over isometric growth (1 species, *b* values = 2.96). For the 5 species the growth in length was superior to weight increase, in one species the growth in length was accompanied by weight increase.

DISCUSSION

The present study provides for the first time information about densities and length-weight relationships (LWRs) of the most abundant bivalve species found on the Zarzis coast. Findings of recent research indicate that densities and biomasses varied substantially from one species to another. A stock size assessment of these target species across quadrats revealed mean density values ranging from 0.47 to 6.10 indiv. m^{-2}, and mean biomass values from 1.83 to 10.34 g m^{-2}. The highest density and biomass values were recorded for *M. pulchella* and *P. aureus*, respectively. Despite the small number of some of the studied bivalve species and the mortality of adult individuals, the littoral zone supports an extraordinary stock estimated at over 491 tons.

As follows from this study, the colonised area presents more than 5.8% of the total biomass of cockle *C. glaucum* in the Gulf of Gabes. A similar gradient was observed in the clam species *R. decussatus* and *P. aureus*, with about 86 and 166 tons or 8% and 13%, respectively, of their total biomasses in the Gulf of Gabes (unpublished data). Our sampling efforts led to an estimation of the local conditions (heterogeneity of abundance and presence of many parameters influencing the distribution). It appears that development of this population has been accompanied by major impacts at numerous levels (e.g., physicochemical, edaphic and hydrological factors of the study area). Stergiou *et al.* (1997) clarified that temperature and food potentials are the most important factors affecting phenotypic differences in growth patterns and maximum sizes in a variety of marine organisms. The concurrent increase in water temperatures and phytoplankton levels (unpublished data) on the Zarzis coast promotes rapid growth rates in many local bivalve species. Other mechanisms structuring bivalves populations include soft bottoms and organic matter content. The high diversity of shellfish species is particularly interesting when the relative organic matter content, depth (< 1 m) and muddy-sandy bottom are considered. In fact, these factors can provide ecological conditions able to maintain highly diverse reef communities in a coastal lagoon.

The bivalve species are more frequent and abundant in areas sheltered by seagrasses *C. nodosa* and *Z. noltei*, which cover more than 50% of muddy-sandy seabeds. The heterogeneity of the geographical distribution of the target species was found to be significantly correlated with the distribution of seagrass. This positive correlation was probably related to the main organic source provided by *C. nodosa*. The *C. nodosa* detritus is the richest in organic carbon and is the dominant source of primary organic matter. As a result, the sites colonised by it provide good conditions for the proliferation of clams as this species improves the food resources and dissolved oxygen levels. The same conclusion was reached by Vilela (1950) for natural populations of *R. decussatus* in Portugal. Several studies have confirmed the correlation between patterns of community structure and primary production. In particular, local abundance and biomass of filter feeders was found to be correlated with both intertidal productivity and nearshore primary productivity (Menge & Olson, 1990). Other parameters such as light and tides may also contribute (da Costa *et al.*, 2013).

All the studied species presented high determination coefficients in LWRs. In addition, the prevalence of negative and isometric growth and the absence of positive growth is a very interesting phenomenon, since these species are typical inhabitants of sandy or sandy-muddy bottoms. In practice this means that during ontogeny bivalve shells become progressively and rapidly longer than weighty. This phenomenon may be explained by the fact that the density of substrata is a limiting factor on firmer sediments, therefore the *b* values of LWRs may not exceed three in such environments.

The present observations were not in agreement with those reported in previous works by Gaspar *et al.* (2001) and later by Derbali (2011). These authors argued that most studied bivalve species displayed positive or isometric growth. Thayer (1975) believed that these ontogenetic changes could be related to the different lifestyles between adult individuals (more sedentary and inhabiting deeper sedimentary bottoms) and juveniles (active burrowers). For these species, the negative and isometric growth may be a reflection of their burrowing strategies or, to a lesser extent, of the burrowing difficulties associated with their globous shape.

In our study, the hydrodynamic conditions were similar across the sampling area and it might be assumed that relative growth was influenced by other parameters such as depth, sediment type, the burrowing behaviour of the studied species and their subsequent strategies to counter dislodgement and avoid predation. Indeed, Gaspar *et al.* (2002) found that some interesting connections between environmental conditions, bivalve lifestyles and species morphometric relationships were reported for many bivalve species.

Species of the families Veneridae, Tellinidae, Mactridae and Lucinidae, namely *R. decussatus* (Linnaeus, 1758), *P. aureus* (Gmelin, 1791), *M. pulchella* (Lamarck, 1818), *M. stultorum* (Linnaeus, 1758) and *L. orbiculatus* (Poli, 1791), displayed negative allometry, which may be attributed to their shallower bathymetric distribution compared to the cockle species *C. glaucum* of the family Cardiidae. According to Gaspar *et al.* (2002), the negative growth and elongated shape may be an adaptive strategy to improve burrowing efficiency and depth within the substrate.

Further interesting results were detected with regard to other encountered species which, despite being deep burrowing bivalves, displayed isometric growth,

for instance, the species of the family Cardiidae; this appears to be in contradiction with other studies of these species in several other geographical areas (Ansell & Lagardère, 1980; Ramon, 1993; Gaspar *et al*., 2001; Derbali, 2011). Disagreements reported on species morphometric relationships may be a result of environmental conditions varying between different geographical areas. In many cases, investigations were conducted in the Mediterranean and Adriatic Seas, where the habitats differ considerably from those in Tunisian waters. Therefore, Gaspar *et al*. (2001 & 2002), Tlig-Zouari *et al*. (2009 & 2010) and Derbali *et al*. (2011 & 2012) argued that these environmental conditions could potentially lead to variations within bivalve species and between localities. Moreover, the size ranges of many shellfish species from different geographical areas are highly variable, which complicates comparison among surveys.

Indeed, estimation of LWRs is necessary and important as it provides information on the condition of a population; it is also a widely applied approach in the study of the dynamics of exploited stocks and an effective tool used for basic research and management strategies in fisheries. Moreover, the parameters affecting length-weight relationships can be used to enhance management and conservation and allow future comparisons between different populations of the same species living in similar or different ecosystems. Future studies could be conducted in many ways: i) stocks assessment should be carried out each year in order to track variations in bivalve stocks and changes in their structures, ii) the relationship between species density and abiotic and biotic parameters should be investigated in detail, iii) in future research, more consideration should be given to studies of weight of the visceral mass as opposed to those of total weight, since that analysis is also and particularly applicable to other fishery resources such as crustaceans, cephalopods, and fish.

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DOLŽINSKO-MASNI ODNOS IN GOSTOTA ŠKOLJK NA GOJIŠČU ŠKOLJK V PREDELU ZARSISA (TUNIZIJA, OSREDNJE SREDOZEMSKO MORJE)

Abdelkarim DERBALI, Aymen HADJ TAIEB & Othman JARBOUI
Institut National des Sciences et Technologies de la Mer (INSTM). BP 1035 Sfax 3018, Tunisia
e-mail: derbali10@gmail.com; abdelkarim.derbali@instm.rnrt.tn

POVZETEK

*Avtorji poročajo o masno-dolžinskem odnosu za najpogostejše in najštevilčnejše vrste školjk na obrežnem predelu v Zarzisu (južna Tunizija). Leta 2018 so opravili sistematske raziskave na sedimentnem dnu do 1 m globine. Raziskava je obelodanila prve rezultate o masno-dolžinskem odnosu in gostoti za šest vrst školjk (*Ruditapes decussatus*,* Polititapes aureus*,* Moerella pulchella*,* Cerastoderma glaucum*,* Mactra stultorum *in* Loripes orbiculatus*) iz petih družin. Gostote teh tarčnih vrst so bile v razponu od 0,47 do 6,10 osebkov m^{-2}*, biomase pa od 1,83 do 10,*34 g m*$^{-2}$. Rezultati so pokazali negativno rast pri petih vrstah in izometrično rast pri eni vrsti. Pričujoči podatki so pomembni za upravljanje in ohranjanje teh vrst.

Ključne besede: Mollusca, Bivalvia, dolžinsko-masni odnos, alometrična rast, obala Zarzis, Tunizija

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THE DIVERSITY OF MOTHS (LEPIDOPTERA: HETEROCERA) OF SIGNIFICANT LANDSCAPE DONJI KAMENJAK AND MEDULIN ARCHIPELAGO, ISTRIA, CROATIA

Toni KOREN
Association Hyla, Zagreb, Croatia, Association Hyla, Zagreb, Croatia
e-mail: toni.koren@hhdhyla.hr

ABSTRACT

The moth diversity of Significant landscape Donji Kamenjak and Medulin archipelago was surveyed during 2021. Together with the data collected in several field trips in previous years, 446 species of moths have been recorded in the area so far. Many of the recorded species belong to the seldomly recorded moth species in Croatia and some represent only the second or third finding for the country while for several species have been recorded in Istria peninsula for the first time. One species, Eupithecia ultimaria *Boisduval, 1840 is reported as new to the fauna of Croatia. Three main threats were established for the moth diversity, natural succession due to the lack of regular grazing, a large network of paths and roads leading to the habitat phragmentation and the high pressure of the vehicles in summer months resulting in the rise of the carbonate dust from the macadam roads on surrounding grasslands and vegetation.*

Key words: calcareus grasslands, maquis, faunistic, light trapping, Natura 2000

LA DIVERSITÀ DELLE FALENE (LEPIDOPTERA: HETEROCERA) DEL PAESAGGIO SIGNIFICATIVO DI DONJI KAMENJAK E DELL'ARCIPELAGO DI MEDULIN, ISTRIA, CROAZIA

SINTESI

La diversità delle falene del Paesaggio significativo di Donji Kamenjak e dell'arcipelago di Medulin è stata studiata nel corso del 2021. Insieme ai dati raccolti in diverse escursioni sul campo negli anni precedenti, finora sono state registrate 446 specie di falene nell'area. Molte delle specie registrate appartengono a specie di falene raramente registrate in Croazia e alcune rappresentano solo il secondo o il terzo ritrovamento per il Paese, mentre diverse specie sono state registrate per la prima volta nella penisola istriana. Una specie, Eupithecia ultimaria *Boisduval, 1840, è stata segnalata come nuova per la fauna della Croazia. Sono state individuate tre minacce principali per la diversità delle falene: la successione naturale dovuta alla mancanza di pascolo regolare, una vasta rete di sentieri e strade che porta alla frammentazione dell'habitat e l'elevata pressione dei veicoli nei mesi estivi che provoca l'aumento della polvere di carbonato dalle strade in macadam sulle praterie e sulla vegetazione circostanti.*

Parole chiave: praterie calcaree, macchia mediterranea, faunistica, trappole di luce, Natura 2000

INTRODUCTION

The Istrian peninsula (45°12'N 13°54'E) is located in the northern part of the Adriatic Sea, between the Gulfs of Trieste and Kvarner. It extends over three countries: Croatia, Slovenia, and Italy. Only a small part in the north lies in Italy, and the north-western part is in Slovenia. Along the northern border of the County the countryside is hilly, including part of the mountain massif of Ćićarija with the highest peak Veliki Planik (1272 m). In general, Istria is a mosaic of different habitat types and small villages. One third of the peninsula is covered by woodland, while the remaining open land comprises agricultural areas with grasslands, meadows and arable land. Istria can be divided into three different geological areas. The northern and north-eastern part, with relatively scarce vegetation and bare Karst surfaces, is called 'White Istria'. South-west of this is an area of lower flysch tracts consisting of impermeable marl, clay and sandstone known as 'Grey Istria'. Most of the coastline is comprised of limestone terraces covered with red earth, giving it the name 'Red Istria'. One-third of the peninsula is covered by woodland, while the remaining open land comprises agricultural areas with grasslands, meadows, and arable land.

The moth diversity of the Istria peninsula is in general poorly known and it has been studied most intensively in the first half of the 20th century when it was still a part of the Austro-Hungarian empire. At the time several parts of the peninsula were investigated in more detail, including Brijuni islands (Rebel, 1913a, 1914), Mt. Učka, and the adjacent coastal regions (Rebel, 1924, 1913b, 1912; Schawerda, 1920). Recently two studies were published, but dealing with a limited number of localities in the central part of Istria, the area around Pazin (Koren & Ladavac, 2013) and the Motovun forest (Koren *et al.*, 2015). No recent studies for the southern part of Istria exist, and the historical data is rather scarce and imprecise (Galvagni, 1909; Prohaska, 1922; Stauder, 1933, 1932, 1930, 1929, 1926, 1925).

The area of Donji Kamenjak represents one of the best-preserved complexes of grassland habitats in the southern part of the peninsula. It is one of the last remaining natural areas in the area, which remained largely preserved and uninhabited mainly due to the long-term presence of the army in the area from the time of the Austro-Hungarian empire up to several decades ago. Calcareus grasslands and their successive states cover most of the area and areas such unique habitats not present anywhere else in southern Istria. Such grasslands are one of the scarcest habitats across the whole peninsula, especially in the coastal zones which are almost completely under the strong influence of tourism and intensive development. Grasslands are also key habitats for many insect species across the temporate region of Euroasia, especially Lepidoptera (Settele *et al.*, 2008). This is easily seen in butterflies across the peninsula, with grasslands being limiting factors for the presence of many previously more widespread species (Koren *et al.*, 2018). In the current times in the area of Donji Kamenjak, such grasslands are usually small in surface and are in most cases partially overgrown and surrounded by other habitats that are the results of their succession like garigues, maquis and forests. Still, this is an area of immense floristic biodiversity. The flora of the area has been studied in more detail and more than 430 plant taxa have been identified in the area (Paljar *et al.*, 2009). The fauna of the area is much less investigated and for some insect groups completely unknown. With respect to Lepidoptera, only the data about butterflies of the area were so far partially published (Koren *et al.*, 2018). Nothing about the moth diversity of Donji Kamenjak is known in the scientific literature.

This work aims to present the first systematic survey of moths (Lepidoptera: Heterocera) of Donji Kamenjak to create a baseline for future moth studies and population monitoring.

MATERIAL AND METHODS

Study area

Donji Kamenjak is the southernmost part of the Istrian peninsula, located just south of the village Premantura, near Pula. It has been declared protected as Significant Landscape Donji Kamenjak and Medulin Archipelago (in 1996 by the Assembly of the County of Istria owing to landscape and natural and cultural values (Anonymous, 1996, 2002). Significant landscapes are one of the categories of national protected areas in Croatia. Their purpose is to protect the landscape values, biodiversity or cultural and historical values or the landscape and preserve their unique features. The land area of significant landscape, except for the islands, is included in Natura 2000 ecological network (HR2000616 – Donji Kamenjak).

The area of Donji Kamenjak is a small peninsula, connected by a narrow part with the mainland, with very indented and long coastline, which gives it the characteristics of an island. The investigated area is characterized by a Mediterranean climate (Zaninović, 2008).

The area of Donji Kamenjak belongs to the Mediterranean vegetation region and the largest part of the area (197,09 ha) is covered in coastal evergreen

Tab. 1: List of surveyed localities in the area of Donji Kamenjak. Coordinates are given in WGS84 coordinate system, z - altitude.
Tab. 1: Seznam raziskovanih nahajališč na območju Donjega Kamenjaka. Koordinate so podane v koordinatnem sistemu WGS84, z - nadmorska višina.

	Locality	WGS N	WGS E	Z
1.	Donji Kamenjak, Rt. Grakalovac, educational path “dinosaurs”, edge of coastal evergreen forests and maquis, grasslands As. *Chrysopogoni-Euphorbietum nicaeensis* H-ić. (1956) 1958	44,79244	13,90852	8
2.	Donji Kamenjak, near the pond, As. *Chrysopogoni-Euphorbietum nicaeensis* H-ić. (1956) 1958	44,793812	13,91231	8
3.	Donji Kamenjak, Plovanije, edge of coastal evergreen forests and maquis, grasslands As. *Chrysopogoni-Euphorbietum nicaeensis* H-ić. (1956) 1958 with a significant presence of *Juniperus oxycedrus* bushes	44,783447	13,90793	0
4.	Donji Kamenjak, west of Školjić bay, edge of coastal evergreen forests and maquis, grasslands As. *Chrysopogoni-Euphorbietum nicaeensis* H-ić. (1956) 1958 with a significant presence of *Juniperus oxycedrus* bushes	44,784853	13,91138	10
5.	Donji Kamenjak, slopes near bay Portić, As. *Chrysopogoni-Euphorbietum nicaeensis* H-ić. (1956) 1958	44,778868	13,91144	0
6.	Donji Kamenjak, Radovica, Ivanšovica, As. *Chrysopogoni-Euphorbietum nicaeensis* H-ić. (1956) 1958	44,775746	13,90846	0
7.	Donji Kamenjak, bay Debeljak, coastal evergreen forests and maquis	44,771009	13,91726	0

forests and maquis (Ljubičić & Bogdanović, 2014). The grasslands are the second largest habitat type in the area and cover 67,63 ha of Donji Kamenjak. The two most prevalent grassland types are Sub-Mediterranean and epimediterranean dry grasslands (*Scorzonero-Chrysopogonetalia* Horvatić. et Ht. (1956) 1958) rocky pastures of the order *Chrysopogoni-Euphorbietum nicaeensis* Horvatić (1956) 1958 (Ljubičić & Bogdanović, 2014). On many grasslands stands of juniper (*Juniperus oxycedrus*) are a common occurrence, and in some places succession toward garrigues and maquis is evident. Agricultural areas in the area used to be intensively cultivated, while today they are mostly neglected. Parts of the coastal zones have been planted with allochthonous *Pinus halepensis* to provide shade to numerous tourists in the summer months. Aside from the natural succession, touristic activity seems to be the main threat to the biological diversity of the area including excessive traffic, especially in the summer months (Carić & Jakelić, 2018). At that time, dust with macadam covered almost all vegetation within a radius of a few meters from the road.

Moth survey

This survey was mainly conducted on a total of 30 nights from February to December 2021 on seven localities (Tab. 1). The data were supplemented by observations made between 2014 and 2020 in the same area. Two main light-trapping sources were used. The primary method was light tent-pyramids consisting of a metal frame, UV lamps connected to a 12 V battery and covered with a white canvas. During each visit, six tent pyramids were used, distanced about ten meters apart. The second method was the usage of a 6W 12V Portable Heath Moth Trap which was left on site then collected the following morning. Two to three Portable Heath Moth Traps were used per locality and night. Both methods were used at each locality, depending on the weather conditions, mainly strong winds that are a common occurrence in the area, and does not allow for the standing light-tents to be used.

The android application and digital platform Biologer were used to record field data during this research (Popović *et al.*, 2020). The moths that could not be identified in the field were collected, prepared, and stored in the author’s private collection (Collection Koren in Zagreb). Such specimens were dissected and identified based on their internal genital structures.

Moths were identified by a large number of different identification keys. For the Noctuidae family books from the series, Noctuidae Europeaea were used (Fibiger, 1990, 1993, 1997; Ronkay & Ronkay, 1994, 1995; Ronkay et al., 2001; Hacker et al., 2002; Goater et al., 2003; Zilli et al., 2005; Fibiger et al., 2007, 2009, 2010; Witt & Ronkay, 2011).

For the Geometridae family book series The Geometrid Moths of Europae was used (Hausmann, 2001, 2004; Mironov, 2003, Hausmann & Viidalepp, 2012; Skou & Sihvonen, 2015; Muller et al., 2019). For other larger moths, different available literature was used (Leraut, 2012, 2009, 2006; Macek *et al.*, 2012; Nowacki, 1998)2012; Nowacki, 1998. For Microlepidoptera all the available literature was used including the book series Microlepidoptera of Europe (Gaedike, 2019; Goater *et al.*, 2005; Huemer & Karsholt, 2005, 1999), Pyraloidea of Europe (Slamka, 2019, 2013, 2008, 2006), Tortricidae of Europe (Razowski, 2003) and the Internet website Lepiforum.de (Lepiforum e.V., 2021). The taxonomy of the species follows the Fauna Europaea website (de Jong *et al.*, 2014) with minor changes related to recent taxonomic changes.

The list of surveyed localities, with coordinates and altitudes, is given in tab. 1 while the map is presented in Fig. 1. The habitat on most of the surveyed localities belongs to the grasslands of the association *Chrysopogoni-Euphorbietum nicaeensis* Horvatić. (1956) 1958 (Ljubičić & Bogdanović, 2014). Hovewer, all the grassland fragments are extremely small, usually in some state of succession and always surrounded by maquis, forests and a combination of the habitats. Accordingly, the species from all of the mentioned habitats were attracted to the light traps.

RESULTS

This survey generated more than 2300 moth records generating a total of 446 species (Appendix 1). The moth families are listed in taxonomic order (Kristensen *et al.*, 2007) while the species within each family are listed alphabetically. A small proportion of the overall sample remains unidentified for the present, as their taxonomic status is currently regarded as uncertain.

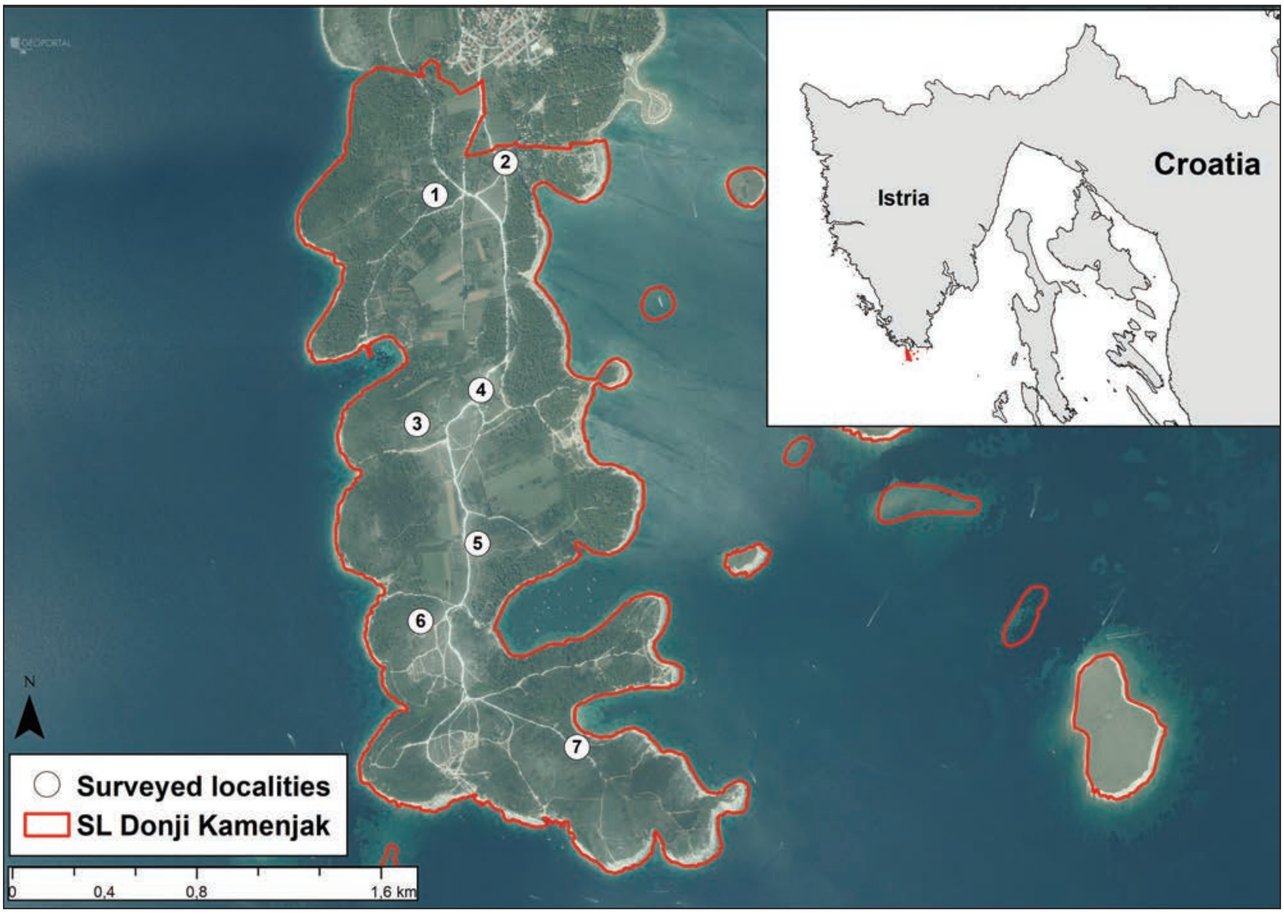


Fig. 1: Surveyed localities on Significant landscape Donji Kamenjak and Medulin Archipelago. Locality numbers correspond to the ones given in Tab. 1.
Sl. 1: Raziskane lokacije na Pomembni krajini Donji Kamenjak in Medulinski arhipelag. Številke krajev ustrezajo tistim v Tab. 1.

DISCUSSION

Historical researches of moth diversity are almost non-existent for most parts of Croatia, and this is particularly true for the area of Donji Kamenjak. Either researchers who have visited the current borders of the Republic of Croatia have not visited the Kamenjak area during their work or else they have not yet published their results. The closest historical records refer to the toponym Pula (Rebel, 1904; Galvagni, 1909; rebel, 1914; Schawerda, 1919; Stauder, 1914, 1920, 1923a, 1923b, 1925, 1926, 1927, 1929, 1930, 1932, 1933; Witt 1987), but it is not clear exactly where the finds were collected in the Pula area. Since Premantura is a historical settlement, we can conclude that in the case of former researchers collecting in the area around Premantura (including Donji Kamenjak), they would most likely use the toponym Premantura (Promontore in Italian). As this is not the case, it is most probable that no targeted moth collecting previously occurred in the area of Donji Kamenjak.

The recorded number of 446 moth species represents a first baseline for the moth diversity of Donji Kamenjak, as well the first recent survey of southern Istria. Since there are no Red lists or Red books of moths in Croatia, it is very difficult to put the collected data on the endangerment of moths in a meaningful perspective. Nevertheless, it is possible to give an overview of the rarer or more significant species recorded by this research based on the prior number of observations or their distribution.

The fauna of the moths of Donji Kamenjak has an extremely large share of true Mediterranean species of moths, that are related to warmer habitats that are primarily found on the Adriatic coast and most of the islands in Croatia. However, many of these species have never been recorded so far north, i.e. in the area of the Istrian peninsula.

One such species is *Ophiusa tirhaca* (Cramer, 1773) (Fig. 2a), a larger Noctuidae species with a wingspan of up to 50 mm. Adults fly in several generations, between March and October. The caterpillars of this species feed on the leaves of various shrubby plants, including the genus *Pistacia*. In Croatia, this species occurs exclusively in the coastal area and the northernmost finds so far come from the islands of Krk (Habeler, 2003) and Lošinj (Schawerda, 1927). The observations from Donji Kamenjak represent the northernmost distribution points in Croatia. While is most probable that the species has a permanent population in the area, it is also a known migrant that has been recorded at many localities across Europe outside its natural range.

Another noteworthy record is *Xylocampa areola* (Esper, 1789) (Fig. 2b), which has been so far recorded from Lošinj Island (Galvagni, 1921), in the region of the Neretva River (Kučinić *et al*., 1998) and Lokrum island near Dubrovnik (Koren, 2020). The population from Donji Kamenjak represents the northernmost occurrence of this species in the Balkan peninsula. This species is generally common in the early spring, regularly visiting lights.

While the area of Donji Kamenjak is strongly thermophilic without any wetland vegetation, singular observation wetland moths were gathered during this survey. Examples of such species are the species *Rhizedra lutosa* (Hübner, 1803) (Fig. 2c) and *Simyra albovenosa* (Goeze, 1781). Both species can be considered wetland habitat species while *S. albovenosa* belongs to the thermohygrophilous species (Rákosy, 1996). Since these are mostly individual specimens, it is possible that these are migrations through Donji Kamenjak to some more favorable habitats.

From the Erebidae family very interesting is the record of *Araeopteron ecphaea* Hampson, 1914 (Fig. 2d). This very small species that looks more like Microlepidoptera than Erebidae was first recorded in the Croatian fauna last year from the area of Neretva river Delta (Koren, 2021a). The record from Donji Kamenjak is the second for Croatia (Koren, 2021a) and an significant expanse of its range in the country.

Another significant species recorded by this study is *Pachycnemia tibiaria* (Rambur, 1829) (Fig. 2e). It is a Mediterranean species with records from the Balkan peninsula being located mostly in the southern parts of the peninsula (Skou & Sihvonen, 2015). While the distribution is not included in the map presented in (Skou & Sihvonen, 2015), Croatia is mentioned in the text with the remark that no specimens from Croatia exist. This has changed during the last years and the species has been recorded in several areas along the Adriatic coastline and even Bosnia & Herzegovina (Koren & Martinović, 2020). The species is also known from Istria but was last recorded almost a hundred years ago from the vicinity of Pula (Schwingenschuss & Wagner, 1925). The species is relatively numerous in the area of Donji Kamenjak and this population is one of the northernmost populations in Europe in general (Skou & Sihvonen, 2015).

In the area of Donji Kamenjak another interesting, but common Geometridae species is *Tephronia theophilaria* Hausmann, 2019 (Fig. 2f). This species was described only two years ago as a stenoendemic of the northern Adriatic, and it was already known at that time that its distribution included southern Istria (Müller *et al*., 2019). The correct identification was confirmed by the examination of the genital structures (Müller *et al*., 2019).

From the faunistic standpoint, the most interesting is the record of *Eupithecia ultimaria* Boisduval, 1840 (Fig. 3a). This Mediterranean-Turanian species in Europe occurs in Portugal, Spain, France, Italy, and Greece (Mironov, 2003). Only a single male

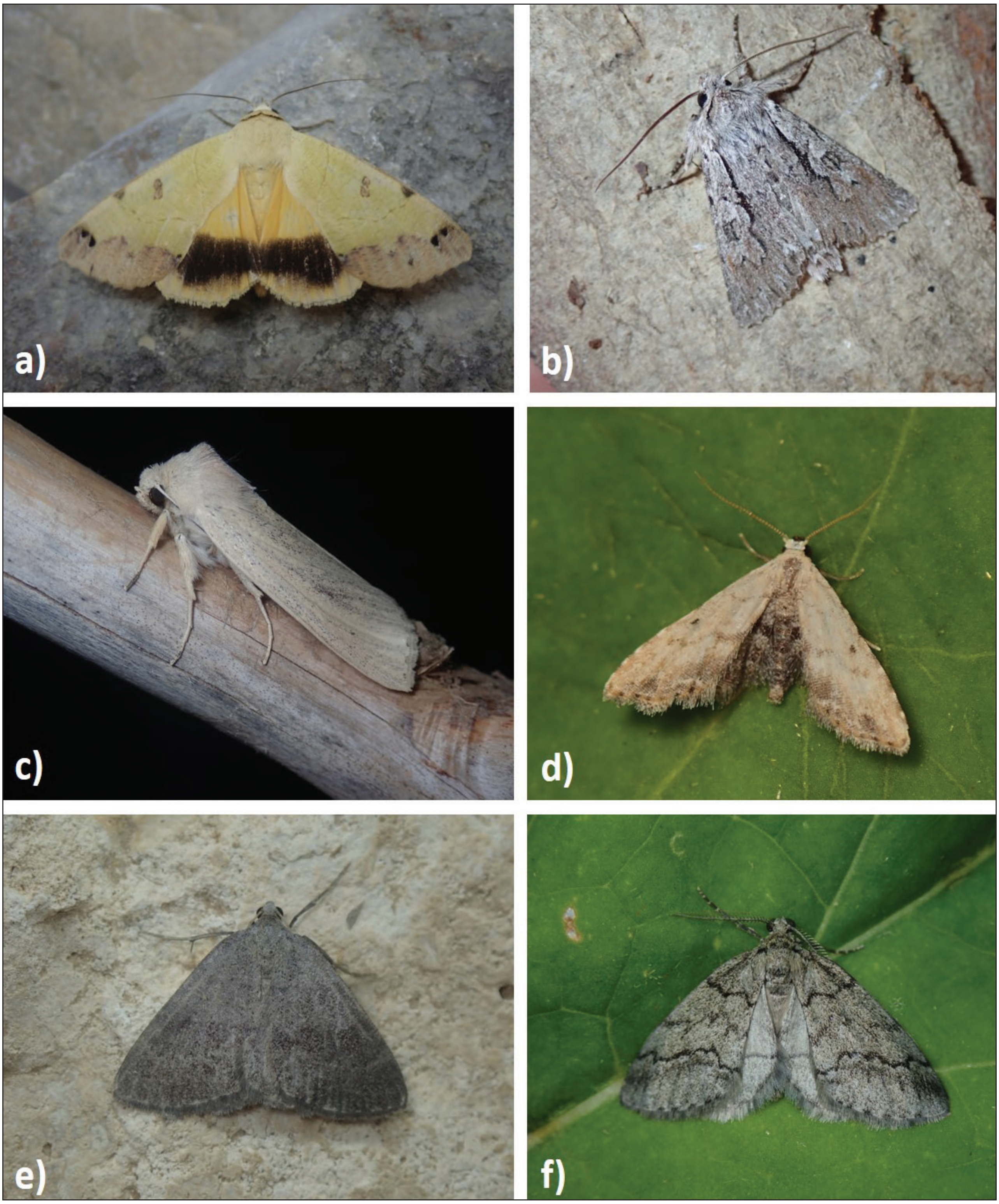


Fig. 2: Interesting moth species recorded at the area of Donji Kamenjak: a) *Ophiusa tirhaca*, ***b)*** *Xylocampa areola*, ***c)*** *Rhizedra lutosa*, ***d)*** *Araeopteron ecphaea*, ***e)*** *Pachycnemia tibiaria*, ***f)*** *Tephronia theophilaria* ***(Photos by T. Koren).***

Sl. 2: Zanimive vrste nočnih metuljev, zabeležene na območju Donjega Kamenjaka: a) *Ophiusa tirhaca*, ***b)*** *Xylocampa areola*, ***c)*** *Rhizedra lutosa*, ***d)*** *Araeopteron ecphaea*, ***e)*** *Pachycnemia tibiaria*, ***f)*** *Tephronia theophilaria* ***(Fotografije T. Koren).***

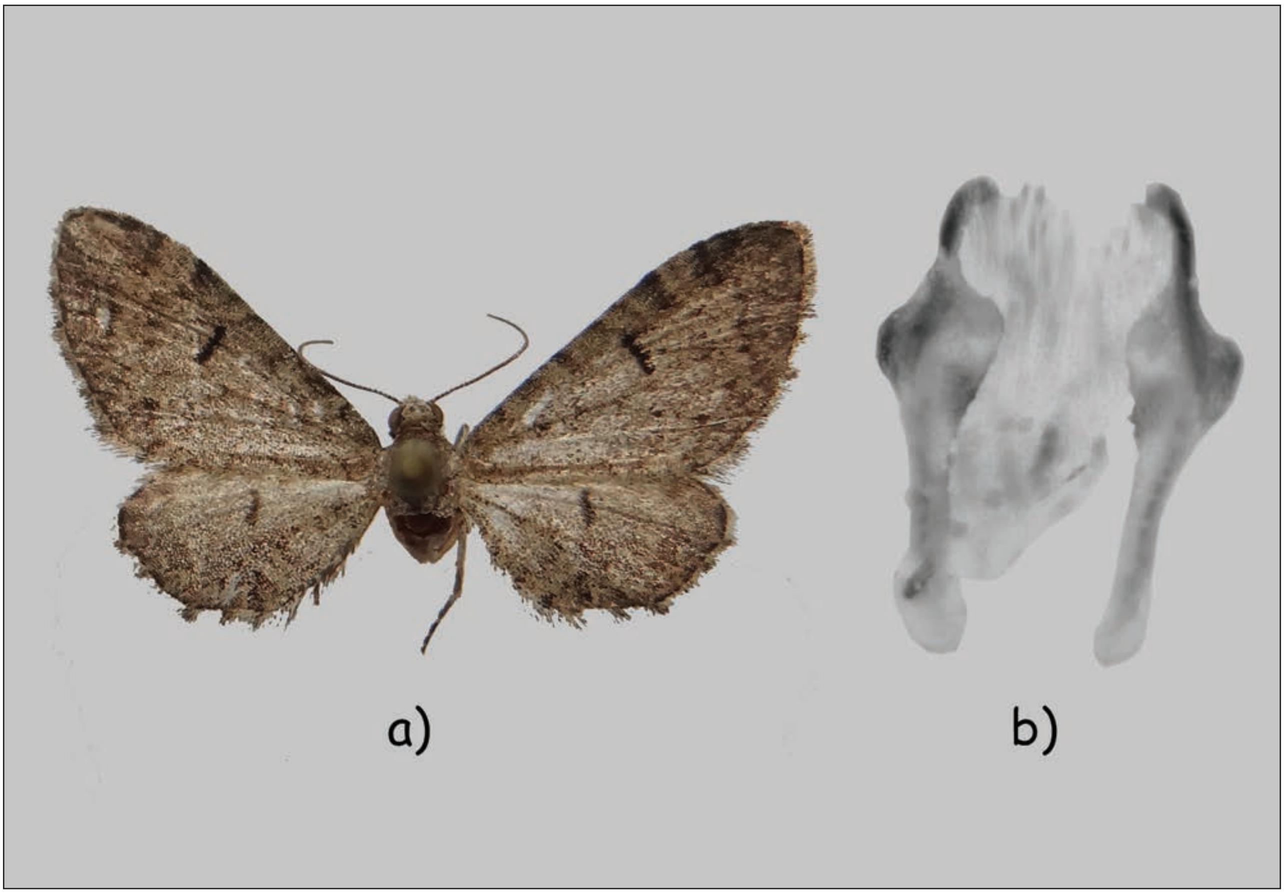


Fig. 3: a) Male of** Eupithecia ultimaria **collected at Donji Kamenjak, b) Tergum A8 of the same specimens showing the distinctive shape for this species (Photos by T. Koren).
Sl. 3: a) Samec** Eupithecia ultimaria**, ujet na Donjem Kamenjaku, b) Tergum A8 istega osebka, ki kaže značilno obliko te vrste (Fotografije T. Koren).

specimen was collected at Donji Kamenjak and was, as was the case with all collected *Eupithecia* specimens, dissected and identified based on its genital structures (Mironov, 2003). This species is very easily identifiable due to the tergum A8 being trapeziform (Fig. 3b), with rounded apical corners and a deep medial hollow in the posterior margin (Mironov, 2003). The habitat of the species is different habitats with tamarisk (Mironov, 2003). No records existed for Croatia before this survey (Mihoci, 2012; Mironov, 2003) and the closest localities were north-western Italy and Greece (Mironov, 2003). This is a new species for the moth fauna of Croatia. While the habitats with tamarisk are the result of grassland sucession, it would not be beneficial to completely restore the grasslands to their natural state. The goal is to maintain the habitat diversity (grasslands, garigues, maquis, forests etc.) in the long run, in order to preserve the diversity of the area which will be beneficial also for the long-term survival of this species.

From the Microlepidoptera families, a large number of records may be interpreted as interesting, but the lack of surveys and checklists of most of the moth families belonging to the smaller moths renders this task rather difficult.

From the Pyralidae family, one of the more interesting species is *Dioryctria robiniella* (Milličre, 1865) (Fig. 4a). This is a rather local and poorly known species whose occurrence in Croatia has been only recently confirmed (Koren, 2021b) even if its presence in the country was known for some time (Speidel & Asselbergs, 2000). While for the correct identification of most species of the genus, the examination of the internal male and female genital structures is necessary, this is not the case with *D. robiniella* which is very different from all other European species and can be easily recognized due to the grey coloring and the distinct black markings. The records from Donji Kamenjak represent the northernmost observations of this species in Croatia and expand the known range also to the Istria peninsula.

Another scarcer Pyralidae species recorded during this survey is *Acrobasis obtusella* (Hübner, 1796) (Fig. 4b). The species has been reported from Croatia only twice (Mann, 1869; Habeler, 2003). It is a species with a Mediterranean distribution for which there are only a few finds for the entire Balkan Peninsula (Plant & Jakšić, 2018).

Acrobasis porphyrella (Duponchel, 1836) has been recorded only the third time for Croatia (Rebel, 1919; Prohaska, 1922). It is a rare species in the whole Balkan peninsula known so far only from Croatia and Albania (Plant & Jakšić, 2018).

Stemmatophora combustalis (Fischer v. Röslerstamm, 1842) (Fig. 4c) belongs to the more attractive Microlepidoptera species. This species is present in Croatia only on the Adriatic coast and the closest finds come from Lovran (Schawerda, 1921) and the island Krk (Habeler, 2003). It is a relatively rare species in Europe with few recent observations (Slamka, 2006). It inhabits dry open habitats where its hostplant, *Erica maniupliflora* grows (Slamka, 2006).

One extremely numerous species of grass moth in the area of Donji Kamenjak is a small species *Metasia corsicalis* (Duponchel, 1833) (Fig. 4d). Only several observations of this species exist for Croatia (Rebel, 1913a; Habeler, 2003; Slamka, 2013) and the only data from Istria originate from Veliki Brijun (Rebel, 1913a). In the area of Donji Kamenjak, this is very numerous and common species arriving at the light traps in great numbers.

Antigastra catalaunalis (Duponchel, 1833) (Fig. 4e) has seldomly been recorded in Croatia (Rebel, 1904, 1914; Klimesch, 1942, Habeler, 2003; Slamka, 2013) and the only record from Istria is from Veliki Brijun island (Rebel, 1914). The observations from Donji Kamenjak are the second record for Istria. The species inhabits different types of dry habitats (Slamka, 2013), and the grasslands of Donji Kamenjak seem to hold a large population of this species.

From the Tortricidae family *Cydia molybdana* (Constant, 1884) (Fig. 4f) is interesting. It is a species whose separation from the related species *Cydia amplana* (Hübner, 1799) has only recently been clarified (Karisch & Pinzari, 2010). The distribution of this species stretches along the Mediterranean coast, and the records for the Kamenjak area are the northernmost distribution records for Croatia (Karisch & Pinzari, 2010).

Several other noteworthy records of resident, but most probably overlooked species were made. For *Kessleria alpicella* (Stainton, 1851) Donji Kamenjak is the second record for Croatia (Huemer & Tarmann, 1991) and the same is true for *Mesophleps corsicella* (Herrich-Schäffer, 1856) with a single record so far (Habeler, 2003). *Eteobalea dohrnii* (Zeller, 1847) has been previously recorded only twice (Habeler, 2001, 2003). *Tebenna micalis* (Mann, 1857) has been recorded in Croatia only twice before (Mann, 1857; Habeler, 2003). It is resident in the surveyed area as more than 15 individuals were observed during this study.

The limited number of observations of some Microlepidoptera species does not imply that the species are rare in Croatia. Indeed, some species may even be very common. The scarcity of records is mostly due to the lack of surveys and publishing of the existing results. The small number of published records may, especially in Microlepidoptera, give an incorrect notion of their rarity (Gumhalter & Kučinić, 2020; Gumhalter, 2021). Also, it may lead to the conclusion that nothing is known about Microlepidoptera of Croatia and many species could be reported as new for the country (Richter & Pastorális, 2015) which can later be found incorrect (Gumhalter, 2019). To change this, targeted surveys, as well as publishings of existing data, including checklists that contain new and verified literature data, are needed.

In addition to interesting species of moths from a faunistic point of view, one species of European importance was also recorded. *Euplagia quadripunctaria* (Poda, 1761) is listed in Annex II and IV of the Habitats Directive as „animal species of community interest whose conservation requires the designation of special areas of conservation" (Anonymous, 1992) and is one of few moth species protected by the law in Croatia (Anonymous, 2009). This species is rather common in Croatia and present in all three biogeographical regions (Kučinić *et al.*, 2014). While this species is not a target species for Natura 2000 site HR2000616 Donji Kamenjak, its presence in the area is important as in the whole Istria peninsula only one site was designated for this species - HR2001322 Vela Traba (Anonymous, 2015). In the surveyed area this species was recorded in three localities (Tab. 2).

As this survey was conducted predominantly on grasslands (of different succession states), the recorded moth diversity could be used as a baseline for their current status in the area of Donji Kamenjak, especially after change in the management (reintroduction of sheep for example) or habitat restorations. Semi-natural calcareous grasslands belong to the most species-rich habitat types of Europe (van Swaay, 2002) and their conservation and restoration are required according to the Habitat Directive of the European Union (Anonymous, 1992).

Three main threats to the grassland habitats of Donji Kamenjak were observed. The first and

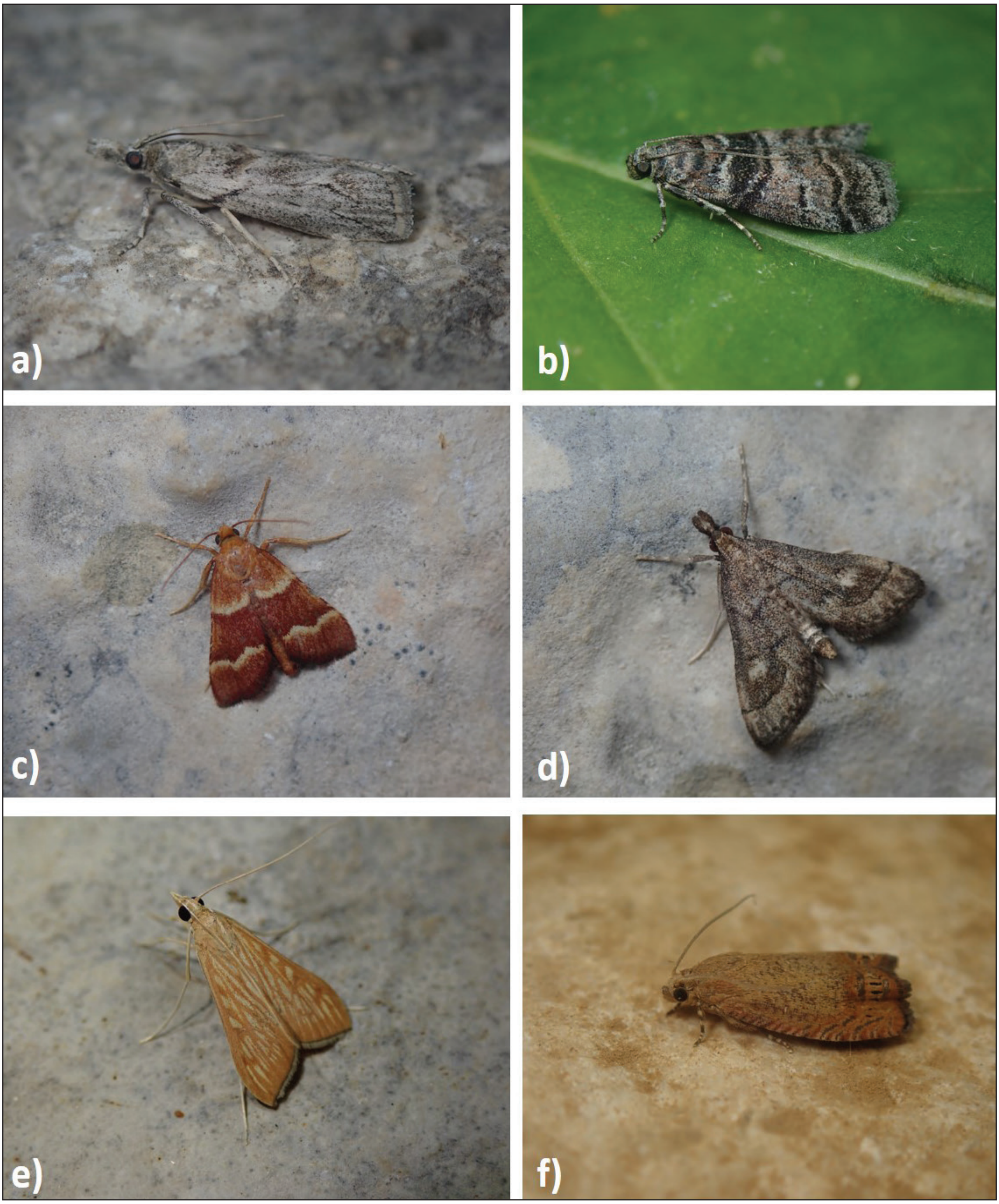


Fig. 4: Some of the interesting Microlepidoptera recorded during this survey: a) *Dioryctria robiniella*, ***b)*** *Acrobasis obtusella*, ***c)*** *Stemmatophora combustalis*, ***d)*** *Metasia corsicalis*, ***e)*** *Antigastra catalaunalis*, ***f)*** *Cydia molybdana* ***(Photos by T. Koren).***

Sl. 4: Nekaj zanimivih Microlepidoptera, zabeleženih med to raziskavo: a) *Dioryctria robiniella*, ***b)*** *Acrobasis obtusella*, ***c)*** *Stemmatophora combustalis*, ***d)*** *Metasia corsicalis*, ***e)*** *Antigastra catalaunalis*, ***f)*** *Cydia molybdana* ***(Fotografije T. Koren).***

most obvious is natural succession. In the area of Donji Kamenjak, grasslands are endangered habitats due to the abandonment of the traditional grazing which was in the area present until recently. Nowadays the sheep that for decades maintained the open grasslands are not present in the area anymore, and the succession, especially with *Juniperus oxycedrus*, is visible in most grasslands. Many private owned grasslands (and former agricultural land) across Donji Kamenjak are completely overgrown and unnatained. The grasslands that are in the public domain are maintained by the employees of the "Kamenjak" Public Institution for the Management of Protected Natural Values in the Medulin Municipality Area. Such grasslands are regularly cleared of *Juniperus oxycedrus, Erica arborea, Pinus halepensis* and similar woody species that grow sporadically on the pastures and are a sign of succession of the grasslands (Ljubičić *et al.*, 2020). The cuttings of such species should be applied as soon as possible because, in the later phase of succession and the development of dense maquis, the process is much more difficult and longer-lasting (Ljubičić *et al.*, 2020). For overgrown grasslands, where scrub biomass is high and needs to be reduced, goats can be used but very carefully because they are difficult to manage (San Miguel, 2008). For larger overgrown areas that belonged to former pastures, the burning method is also effective in eliminating unwanted vegetation of maquis created in the process of progressive succession and results in unique species composition (Moog *et al.*, 2002). However, only the reintroduction of extensive sheep grazing would be a long-term solution. As an optimal grazing load for such grasslands (pastures), moderate-intensity of sheep grazing with 1 to 2 sheep/ha is recommended (Ljubičić & Bogdanović, 2014).

Another observed threat is the extremely large number of macadams, paths, and roads used for traffic by either cars or other smaller motor vehicles. The development and presence of roads can reduce landscape permeability, leading to habitat loss, and increasing habitat fragmentation (Bennett, 2017). This is most visible in small areas like Donji Kamenjak which has a surface of about 4 km^2. This is especially true in the summer months when the number of cars is very high, and the roads became impenetrable barriers due to the constant ongoing traffic. One of the proposals to mitigate this is to reduce the number of roads on which cars are allowed. This practice has already been observed in the study area, where parts of the macadam are blocked by logs or stones, which we strongly support and suggest that it continue. It also makes it impossible to park vehicles on grasslands and further degrade them. To relieve the whole of Donji Kamenjak in the future, alternative ways of entering the area should be considered, which would not be so destructive to nature. A second option is the limitation of the number of vehicles that are allowed to enter daily. The summer months themselves are very dry in the Mediterranean area and unfavorable for flora and fauna, and such a large anthropogenic impact can only further complicate the survival of moth fauna in the area of Donji Kamenjak.

The third observed problem for which it is quite difficult to determine the direct impact on moths is excessive traffic in the summer months and the chalk dust it raises on the surrounding grasslands and vegetation. This is largely reflected in the white cover on most lawns, shrubs, and trees located near the roads and can have a negative impact on flora and fauna due to inhibition of photosynthesis, reduced ability to absorb UV radiation and CO2 (Ozimec *et al.*, 2016). Forest edges or bush edges are important habitats for many species and it is especially important to maintain such habitats in the right way. Finally, macadam-type road is a threat due to repeatedly rain rinsing of the dust material required for road maintenance. The chalk dust is rinsed from the road surface towards the grassland areas which can cause changes in soil composition and even fragmentation of grassland areas.

All of the mentioned problems should be addressed urgently to halt ongoing loss of biodiversity in the area.

CONCLUSIONS

With this survey, a previously completely unsurveyed area of Croatia in terms of moth diversity becomes one of the better-studied areas in the country. Accordingly, the basic moth diversity, especially of the larger moths of Donji Kamenjak has been established, while in Microlepidoptera additional targeted surveys are needed. This should be done by including experts for more difficult groups or the implementation of new methods like DNA barcoding (Huemer *et al.*, 2014). Nevertheless, this study should be regarded as a baseline and a first step in the long-term protection of the moth diversity of Donji Kamenjak. Such faunistic works are especially important for the appropriate management of protected areas as well as their presentation to the visitors and the interested public.

Still, this work is pure faunistic and should be regarded as the first step into more complex ecological studies which would determine the changes in species abundance and composition

following the natural succession or/and management actions that could take place in this area. As moths are suitable ecological indicators for the open and forested habitats, which has been proven in the Carpathian grasslands (Šumpich & Konvička, 2012), further steps on Donji Kamenjak would be to select permanent plots on which long-term monitoring of moths should take place. In this case, the light trapping effort should be measurable and repeatable, and this should be done over a longer period. Only with this way any changes in moth diversity of this important and protected area could be monitored.

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Appendix 1: Systematic list of moths recorded in the area of Donji Kamenjak. The location number corresponds to the location numbers in Table 1.
Priloga 1: Sistematičen seznam nočnih metuljev, zabeleženih na območju Donjega Kamenjaka. Številka lokacije ustreza številkam lokacij v Tabeli 1.

	Genus and species	Locality
	Hepialidae	
1.	*Triodia adriaticus* (Osthelder, 1931)	2
2.	*Triodia sylvina* (Linnaeus, 1761)	2, 3
	Adelidae	
3.	*Adela croesella* (Scopoli, 1763)	2
	Plutellidae	
4.	*Plutella xylostella* (Linnaeus, 1758)	2, 3, 6
	Yponomeutidae	
5.	*Kessleria alpicella* (Stainton, 1851)	3
6.	*Yponomeuta evonymella* (Linnaeus, 1758)	3
7.	*Yponomeuta irrorella* (Hübner, 1796)	6
8.	*Yponomeuta padella* (Linnaeus, 1758)	3, 6
	Chimabachidae	
9.	*Diurnea fagella* (Denis & Schiffermüller, 1775)	1
	Cosmopterigidae	
10.	*Eteobalea dohrnii* (Zeller, 1847)	6
11.	*Eteobalea isabellella* (O. G. Costa, 1836)	3, 6
12.	*Pyroderces argyrogrammos* (Zeller, 1847)	2, 3
	Elachistidae	
13.	*Depressaria tenebricosa* Zeller, 1854	5, 6
14.	*Ethmia bipunctella* (Fabricius, 1775)	6, 7
	Gelechiidae	
15.	*Dichomeris marginella* (Fabricius, 1781)	6
16.	*Esperia sulphurella* (Fabricius, 1775)	1
17.	*Mesophleps corsicella* Herrich-Schäffer, 1856	3
18.	*Mesophleps oxycedrella* (Millière, 1871)	3
19.	*Palumbina guerinii* (Stainton, 1858)	2
20.	*Ptocheuusa paupella* (Zeller, 1847)	2
21.	*Tuta absoluta* (Meyrick, 1917)	2

	Genus and species	Locality
	Lecithoceridae	
22.	*Odites kollarella* (O. G. Costa, 1832)	2, 3, 5
	Oecophoridae	
23.	*Batia lambdella* (Donovan, 1793)	3, 6
24.	*Epicallima formosella* (Denis & Schiffermüller, 1775)	3
25.	*Pleurota aristella* (Linnaeus, 1767)	3, 5, 6
	Peleopodidae	
26.	*Carcina quercana* (Fabricius, 1775)	3, 4
	Scythrididae	
27.	*Scythris limbella* (Fabricius, 1775)	3
	Cossidae	
28.	*Dyspessa ulula* (Borkhausen, 1790)	1, 3, 4, 5, 6
29.	*Parahypopta caestrum* (Hübner, 1808)	1, 2, 3, 4, 5, 6, 7
30.	*Zeuzera pyrina* (Linnaeus, 1761)	3, 5, 6
	Limacodidae	
31.	*Apoda limacodes* (Hufnagel, 1766)	1
	Zygaenidae	
32.	*Zygaena filipendulae* (Linnaeus, 1758)	5
33.	*Zygaena loti* (Denis & Schiffermüller, 1775)	3
34.	*Zygaena punctum* Ochsenheimer, 1808	1
	Choreutidae	
35.	*Choreutis nemorana* (Hübner, 1799)	3, 6
36.	*Tebenna micalis* (Mann, 1857)	3, 6
	Tortricidae	
37.	*Acleris rhombana* (Denis & Schiffermüller, 1775)*	5
38.	*Acleris variegana* (Denis & Schiffermüller, 1775)*	3, 5
39.	*Aethes sanguinana* (Treitschke, 1830)*	6
40.	*Aethes tesserana* (Denis & Schiffermüller, 1775)*	3
41.	*Aethes williana* (Brahm, 1791)*	6
42.	*Agapeta hamana* (Linnaeus, 1758)	3, 5
43.	*Agapeta zoegana* (Linnaeus, 1767)	3, 6
44.	*Aleimma loeflingiana* (Linnaeus, 1758)	3, 6
45.	*Archips xylosteana* (Linnaeus, 1758)	3

	Genus and species	**Locality**
46.	*Cacoecimorpha pronubana* (Hübner, 1799)	3, 6
47.	*Choristoneura lafauryana* (Ragonot, 1875)	3
48.	*Clepsis consimilana* (Hübner, 1817)	2, 3
49.	*Clepsis pallidana* (Fabricius, 1776)	2, 5
50.	*Cnephasia incertana* (Treitschke, 1835)	3
51.	*Cnephasia stephensiana* (Doubleday, 1849)	3
52.	*Cochylimorpha straminea* (Haworth, 1811)	3
53.	*Cochylis posterana* Zeller, 1847	3, 6
54.	*Cydia fagiglandana* (Zeller, 1841)	1, 3, 5
55.	*Cydia molybdana* (Constant, 1884)*	3, 7
56.	*Cydia pyrivora* (Danilevsky, 1947)*	6
57.	*Cydia splendana* (Hübner, 1799)*	2, 6
58.	*Dichrorampha heegerana* (Duponchel, 1843)	6
59.	*Endothenia gentianaeana* (Hübner, 1799)	2, 6
60.	*Endothenia marginana* (Haworth, 1811)	3, 6
61.	*Epinotia dalmatana* (Rebel, 1891)	6
62.	*Epinotia festivana* (Hübner, 1799)	1
63.	*Eucosma albidulana* (Herrich-Schäffer, 1851)	5
64.	*Gypsonoma aceriana* (Duponchel, 1843)	3
65.	*Lobesia botrana* (Denis & Schiffermüller, 1775)	2, 3
66.	*Lobesia quaggana* Mann, 1855	3, 6
67.	*Lozotaeniodes cupressana* (Duponchel, 1836)	3, 5, 7
68.	*Notocelia cynosbatella* (Linnaeus, 1758)	3
69.	*Notocelia roborana* (Denis & Schiffermüller, 1775)	3, 5
70.	*Pelochrista agrestana* (Treitschke, 1830)	5, 6
71.	*Pseudococcyx tessulatana* (Staudinger, 1871)	3, 6
72.	*Rhyacionia pinicolana* (Doubleday, 1849)	3
73.	*Spilonota ocellana* (Denis & Schiffermüller, 1775)	3
74.	*Tortrix viridana* Linnaeus, 1758	3
75.	*Zeiraphera griseana* (Hübner, 1799)	2
	Crambidae	
76.	*Achyra nudalis* (Hübner, 1796)	1, 4
77.	*Agriphila inquinatella* (Denis & Schiffermüller, 1775)*	3, 6

	Genus and species	**Locality**
78.	*Agriphila latistria* (Haworth, 1811)*	2
79.	*Agriphila tolli* (Bleszynski, 1952)*	2, 3, 4, 6
80.	*Anania crocealis* (Hübner, 1796)	1
81.	*Anania stachydalis* (Germar, 1821)	6
82.	*Anania terrealis* (Treitschke, 1829)	2
83.	*Anania testacealis* (Zeller, 1847)	3, 5, 6
84.	*Anania verbascalis* (Denis & Schiffermüller, 1775)	2, 3, 4, 5, 6
85.	*Angustalius malacellus* (Duponchel, 1836)	2
86.	*Antigastra catalaunalis* (Duponchel, 1833)	5
87.	*Aporodes floralis* (Hübner, 1809)	1, 3, 6
88.	*Catoptria pinella* (Linnaeus, 1758)*	1, 3, 5, 6
89.	*Chrysocrambus linetella* (Fabricius, 1781)	3
90.	*Cydalima perspectalis* (Walker, 1859)	1, 2, 3
91.	*Diasemiopsis ramburialis* (Duponchel, 1834)	2
92.	*Dolicharthria punctalis* (Denis & Schiffermüller, 1775)	1, 3, 5, 6
93.	*Duponchelia fovealis* Zeller, 1847	2, 3, 5, 7
94.	*Ecpyrrhorrhoe diffusalis* (Guenée, 1854)	3
95.	*Ecpyrrhorrhoe rubiginalis* (Hübner, 1796)	5, 7
96.	*Euchromius bella* (Hübner, 1796)*	3, 5
97.	*Euchromius ramburiellus* (Duponchel, 1836)*	3
98.	*Euchromius superbellus* (Zeller, 1849)*	3
99.	*Hellula undalis* (Fabricius, 1781)	4, 7
100.	*Loxostege sticticalis* (Linnaeus, 1761)	3, 5, 6
101.	*Mecyna asinalis* (Hübner, 1819)	1, 2, 3, 4, 5, 6, 7
102.	*Metacrambus carectellus* (Zeller, 1847)	1, 3, 4, 5, 6
103.	*Metasia corsicalis* (Duponchel, 1833)	2, 3, 5, 6, 7
104.	*Metasia ophialis* (Treitschke, 1829)	1, 3, 4
105.	*Nomophila noctuella* (Denis & Schiffermüller, 1775)	1, 2, 3, 4, 5, 6, 7
106.	*Palpita vitrealis* (Rossi, 1794)	1, 2, 3, 4, 5, 6, 7
107.	*Pediasia contaminella* (Hübner, 1796)	3, 4, 5
108.	*Pleuroptya ruralis* (Scopoli, 1763)	3
109.	*Pyrausta aurata* (Scopoli, 1763)	1, 2, 3, 4, 5, 6
110.	*Pyrausta despicata* (Scopoli, 1763)	1, 2, 3, 4, 5, 6

	Genus and species	Locality
111.	*Pyrausta sanguinalis* (Linnaeus, 1767)	3, 4
112.	*Pyrausta virginalis* Duponchel, 1832	1, 2, 3, 5
113.	*Sclerocona acutella* (Eversmann, 1842)	2
114.	*Scoparia pyralella* (Denis & Schiffermüller, 1775)	3
115.	*Sitochroa palealis* (Denis & Schiffermüller, 1775)	1, 3
116.	*Sitochroa verticalis* (Linnaeus, 1758)	2, 3
117.	*Udea ferrugalis* (Hübner, 1796)	1, 3, 4, 5, 6
118.	*Uresiphita gilvata* (Fabricius, 1794)	2, 3, 4, 5, 6, 7
119.	*Xanthocrambus saxonellus* (Zincken, 1821)	2, 3, 4, 5, 6
	Pyralidae	
120.	*Acrobasis fallouella* (Ragonot, 1871)*	1, 3
121.	*Acrobasis obtusella* (Hübner, 1796)	5, 6
122.	*Acrobasis porphyrella* (Duponchel, 1836)	1, 3, 5
123.	*Acrobasis tumidana* (Denis & Schiffermüller, 1775)	1
124.	*Aphomia sociella* (Linnaeus, 1758)	5
125.	*Apomyelois ceratoniae* (Zeller, 1839)	2
126.	*Bostra obsoletalis* (Mann, 1884)	1, 3
127.	*Dioryctria abietella* (Denis & Schiffermüller, 1775)*	6
128.	*Dioryctria mendacella* (Staudinger, 1859)*	2, 3, 5, 6, 7
129.	*Dioryctria pineae* (Staudinger, 1859)*	1, 2, 3, 4, 5, 6, 7
130.	*Dioryctria robiniella* (Milličre, 1865)*	1, 3, 6
131.	*Dioryctria simplicella* Heinemann, 1863*	6
132.	*Dioryctria sylvestrella* (Ratzeburg, 1840)*	7
133.	*Elegia atrifasciella* Ragonot, 1887*	3
134.	*Ematheudes punctella* (Treitschke, 1833)	1, 3, 4, 5, 6
135.	*Endotricha flammealis* (Denis & Schiffermüller, 1775)	1, 2, 3, 4, 5, 6, 7
136.	*Ephestia welseriella* (Zeller, 1848)	3, 5, 6
137.	*Epischnia illotella* Zeller, 1839	3, 4
138.	*Etiella zinckenella* (Treitschke, 1832)	3
139.	*Homoeosoma sinuella* (Fabricius, 1794)	1, 2, 3
140.	*Hypsopygia costalis* (Fabricius, 1775)	2, 3, 6
141.	*Hypsopygia glaucinalis* (Linnaeus, 1758)	3, 6
142.	*Hypsopygia incarnatalis* (Zeller, 1847)	1, 2, 3, 5, 6, 7

	Genus and species	Locality
143.	*Hypsopygia rubidalis* (Denis & Schiffermüller, 1775)	3, 5
144.	*Hypsotropa limbella* Zeller, 1848	5
145.	*Lamoria anella* (Denis & Schiffermüller, 1775)	3, 5, 6
146.	*Metallostichodes nigrocyanella* (Constant, 1865)	3, 5, 6
147.	*Oncocera semirubella* (Scopoli, 1763)	1, 2, 3
148.	*Pempelia palumbella* (Denis & Schiffermüller, 1775)	5, 6, 7
149.	*Phycita roborella* (Denis & Schiffermüller, 1775)	3
150.	*Pterothrixidia rufella* (Duponchel, 1836)	1, 3, 5, 6
151.	*Pyralis farinalis* (Linnaeus, 1758)	1
152.	*Pyralis regalis* Denis & Schiffermüller, 1775	1, 3, 4, 5, 6
153.	*Stemmatophora brunnealis* (Treitschke, 1829)	3, 5, 6
154.	*Stemmatophora combustalis* (Fischer v. Röslerstamm, 1842)	5, 6
155.	*Stemmatophora honestalis* (Treitschke, 1829)	6
	Brahmaeidae	
156.	*Lemonia taraxaci* (Denis & Schiffermüller, 1775)	3, 4
	Lasiocampidae	
157.	*Dendrolimus pini* (Linnaeus, 1758)	1, 3, 4, 5, 6
158.	*Gastropacha quercifolia* (Linnaeus, 1758)	1, 3, 5
159.	*Lasiocampa quercus* (Linnaeus, 1758)	1, 3, 4, 5, 6
160.	*Lasiocampa trifolii* (Denis & Schiffermüller, 1775)	3, 4, 5
161.	*Trichiura crataegi* (Linnaeus, 1758)	3, 5, 6
	Sphingidae	
162.	*Agrius convolvuli* (Linnaeus, 1758)	2
163.	*Hyles euphorbiae* (Linnaeus, 1758)	1, 3, 4, 5, 6
164.	*Hyles livornica* (Esper, 1780)	1, 3
165.	*Macroglossum stellatarum* (Linnaeus, 1758)	7
166.	*Marumba quercus* (Denis & Schiffermüller, 1775)	3, 4, 5, 6
167.	*Sphinx ligustri* Linnaeus, 1758	5
168.	*Sphinx pinastri* Linnaeus, 1758	3
	Drepanidae	
169.	*Cilix glaucata* (Scopoli, 1763)	1, 2, 3, 4, 7
170.	*Cymatophorina diluta* (Denis & Schiffermüller, 1775)	2
171.	*Thyatira batis* (Linnaeus, 1758)	7

	Genus and species	**Locality**
172.	*Watsonalla cultraria* (Fabricius, 1775)	3
173.	*Watsonalla uncinula* (Borkhausen, 1790)	1, 2, 3, 4, 5, 6, 7
	Geometridae	
174.	*Agriopis bajaria* (Denis & Schiffermüller, 1775)	4
175.	*Agriopis leucophaearia* (Denis & Schiffermüller, 1775)	1, 4, 6
176.	*Agriopis marginaria* (Fabricius, 1776)	3, 4, 5, 6, 7
177.	*Alcis repandata* (Linnaeus, 1758)	1
178.	*Alsophila aescularia* (Denis & Schiffermüller, 1775)	1
179.	*Ascotis selenaria* (Denis & Schiffermüller, 1775)	6
180.	*Aspitates ochrearia* (Rossi, 1794)	2, 3, 4, 5, 6
181.	*Campaea honoraria* (Denis & Schiffermüller, 1775)	1, 3, 4, 5, 7
182.	*Campaea margaritaria* (Linnaeus, 1761)	3
183.	*Camptogramma bilineata* (Linnaeus, 1758)	1, 5
184.	*Catarhoe rubidata* (Denis & Schiffermüller, 1775)	1, 4, 5
185.	*Chemerina caliginearia* (Rambur, 1833)	3, 5, 6, 7
186.	*Chesias capriata* Prout, 1904	5
187.	*Chiasmia clathrata* (Linnaeus, 1758)	3, 6
188.	*Chlorissa cloraria* (Hübner, 1813)	3
189.	*Chloroclystis v-ata* (Haworth, 1809)	3, 4
190.	*Coenotephria ablutaria* (Boisduval, 1840)	1, 3, 4, 5, 6, 7
191.	*Colotois pennaria* (Linnaeus, 1761)	3
192.	*Costaconvexa polygrammata* (Borkhausen, 1794)	3
193.	*Crocallis elinguaria* (Linnaeus, 1758)	1, 4, 5
194.	*Cyclophora porata* (Linnaeus, 1767)	1, 7
195.	*Cyclophora puppillaria* (Hübner, 1799)	1, 3, 4, 5, 6, 7
196.	*Cyclophora ruficiliaria* (Herrich-Schäffer, 1855)*	3
197.	*Cyclophora suppunctaria* (Zeller, 1847)*	2, 6
198.	*Dyscia innocentaria* (Christoph, 1885)	2, 3, 4, 5, 6
199.	*Earophila badiata* (Denis & Schiffermüller, 1775)	3
200.	*Epirrhoe alternata* (Muller, 1764)	1, 3, 4, 5
201.	*Epirrita dilutata* (Denis & Schiffermüller, 1775)*	1
202.	*Eupithecia centaureata* (Denis & Schiffermüller, 1775)	1, 3, 5, 6
203.	*Eupithecia cocciferata* Milličre, 1864*	3
204.	*Eupithecia ericeata* (Rambur, 1833)*	5, 6
205.	*Eupithecia gemellata* Herrich-Schäffer, 1861*	3, 5, 7
206.	*Eupithecia oxycedrata* (Rambur, 1833)*	2, 3, 5, 6
207.	*Eupithecia semigraphata* Bruand, 1850*	2, 3, 5, 6
208.	*Eupithecia ultimaria* Boisduval, 1840*	6
209.	*Gnophos sartata* Treitschke, 1827	4, 5, 6, 7
210.	*Gymnoscelis rufifasciata* (Haworth, 1809)	1, 2, 3, 5, 6, 7
211.	*Heliomata glarearia* (Denis & Schiffermüller, 1775)	3, 5, 6
212.	*Horisme vitalbata* (Denis & Schiffermüller, 1775)	1, 3, 4, 5, 7
213.	*Hypomecis punctinalis* (Scopoli, 1763)	3
214.	*Idaea albitorquata* (Püngeler, 1909)*	3
215.	*Idaea aversata* (Linnaeus, 1758)*	1, 3, 4, 5, 6, 7
216.	*Idaea circuitaria* (Hübner, 1819)	3, 4, 5, 6
217.	*Idaea degeneraria* (Hübner, 1799)	1, 3, 4, 5, 6, 7
218.	*Idaea distinctaria* (Boisduval, 1840)*	1, 3, 5, 6
219.	*Idaea filicata* (Hübner, 1799)	1, 3, 5, 6, 7
220.	*Idaea infirmaria* (Rambur, 1833)*	1, 3, 5, 6
221.	*Idaea leipnitzi* Hausmann, 2004	3, 6
222.	*Idaea obsoletaria* (Rambur, 1833)*	1, 3, 6
223.	*Idaea ochrata* (Scopoli, 1763)	3, 5, 6
224.	*Idaea ostrinaria* (Hübner, 1813)	3, 5, 6
225.	*Idaea politaria* (Hübner, 1799)*	1
226.	*Idaea rubraria* (Staudinger, 1901)*	3
227.	*Idaea rusticata* (Denis & Schiffermüller, 1775)*	1, 2, 3, 4, 5
228.	*Idaea seriata* (Schrank, 1802)*	1, 2, 3
229.	*Idaea serpentata* (Hufnagel, 1767)*	3
230.	*Idaea straminata* (Borkhausen, 1794)*	5
231.	*Idaea subsericeata* (Haworth, 1809)*	1, 2, 3, 5, 6
232.	*Isturgia arenacearia* (Denis & Schiffermüller, 1775)	1, 2, 3, 5, 6
233.	*Larentia malvata* (Rambur, 1833)	2
234.	*Lycia hirtaria* (Clerck, 1759)	3, 5
235.	*Macaria alternata* (Denis & Schiffermüller, 1775)	1
236.	*Menophra abruptaria* (Thunberg, 1792)	1, 2, 3, 4, 5, 6, 7

	Genus and species	Locality
237.	*Microloxia herbaria* (Hübner, 1813)	1, 2, 3, 4, 5, 6
238.	*Nychiodes dalmatina* Wagner, 1909	3, 4, 5, 7
239.	*Nychiodes obscuraria* (de Villers, 1789)	1, 5
240.	*Nycterosea obstipata* (Fabricius, 1794)	3, 5
241.	*Opisthograptis luteolata* (Linnaeus, 1758)	1, 2, 3, 4, 5
242.	*Pachycnemia hippocastanaria* (Hübner, 1799)	1, 3, 4, 5, 6, 7
243.	*Pachycnemia tibiaria* (Rambur, 1829)	6, 7
244.	*Pareulype berberata* (Denis & Schiffermüller, 1775)	3
245.	*Pasiphila rectangulata* (Linnaeus, 1758)	3, 5
246.	*Pennithera firmata* (Hübner, 1822)	3
247.	*Peribatodes correptaria* (Zeller, 1847)	3, 7
248.	*Peribatodes rhomboidaria* (Denis & Schiffermüller, 1775)	1, 3, 4, 5, 6, 7
249.	*Peribatodes umbraria* (Hübner, 1809)	1, 2, 3, 5, 6
250.	*Perizoma flavofasciata* (Thunberg, 1792)	3, 5
251.	*Phaiogramma etruscaria* (Zeller, 1849)	1, 3, 4, 5
252.	*Rhodometra sacraria* (Linnaeus, 1767)	3, 5
253.	*Rhodostrophia calabra* (Petagna, 1786)	4, 6
254.	*Rhodostrophia vibicaria* (Clerck, 1759)	3
255.	*Rhoptria asperaria* (Hübner, 1817)	1, 3, 4, 5, 6, 7
256.	*Scopula corrivalaria* (Kretschmar, 1862)*	6
257.	*Scopula imitaria* (Hübner, 1799)*	1, 3, 4, 5, 7
258.	*Scopula marginepunctata* (Goeze, 1781)*	1, 2, 3, 4, 5, 6
259.	*Scopula nigropunctata* (Hufnagel, 1767)*	3
260.	*Scopula ornata* (Scopoli, 1763)	1, 2, 3, 4, 5, 6, 7
261.	*Scopula rubiginata* (Hufnagel, 1767)	1, 2, 3, 5, 6
262.	*Synopsia sociaria* (Hübner, 1799)	3
263.	*Tephronia theophilaria* Hausmann, 2019*	3, 5, 6
264.	*Thetidia smaragdaria* (Fabricius, 1787)	3, 4, 5
265.	*Timandra comae* Schmidt, 1931	2, 4, 5
266.	*Xanthorhoe ferrugata* (Clerck, 1759)	5
267.	*Xanthorhoe fluctuata* (Linnaeus, 1758)	1, 3
268.	*Xanthorhoe oxybiata* (Milličre, 1872)	3, 4
269.	*Xenochlorodes olympiaria* (Herrich-Schäffer, 1852)	4, 5, 6, 7

	Genus and species	Locality
	Erebidae	
270.	*Amata phegea* (Linnaeus, 1758)	1, 3, 5, 6
271.	*Araeopteron ecphaea* Hampson, 1914	4, 5
272.	*Arctia villica* (Linnaeus, 1758)	3, 5, 7
273.	*Catephia alchymista* (Denis & Schiffermüller, 1775)	3, 5
274.	*Catocala coniuncta* (Esper, 1787)	1, 4, 5
275.	*Catocala conversa* (Esper, 1783)	2
276.	*Catocala nymphaea* (Esper, 1787)	3, 4
277.	*Catocala nymphagoga* (Esper, 1787)	1, 3, 4, 5, 6
278.	*Cymbalophora pudica* (Esper, 1785)	1, 3, 4, 5, 6, 7
279.	*Diacrisia purpurata* (Linnaeus, 1758)	5
280.	*Diaphora mendica* (Clerck, 1759)	3, 5, 7
281.	*Dysauxes ancilla* (Linnaeus, 1767)	1, 3, 4, 5
282.	*Dysauxes famula* (Freyer, 1836)	1, 3, 4, 5, 6, 7
283.	*Dysgonia algira* (Linnaeus, 1767)	1, 3, 4, 5, 6, 7
284.	*Eilema caniola* (Hübner, 1808)	1, 2, 3, 4, 5, 6, 7
285.	*Eilema complana* (Linnaeus, 1758)*	5, 7
286.	*Eilema depressa* (Esper, 1787)	1, 3, 5, 6, 7
287.	*Eilema lurideola* (Zincken, 1817)*	3
288.	*Eilema sororcula* (Hufnagel, 1766)	1, 2, 3, 4, 5
289.	*Eublemma ostrina* (Hübner, 1808)	1, 3, 5, 7
290.	*Eublemma parva* (Hübner, 1808)	1, 3, 4, 5, 6
291.	*Eublemma purpurina* (Denis & Schiffermüller, 1775)	2, 3, 5, 7
292.	*Eublemma viridula* (Guenée, 1841)	1, 2, 3, 4, 5, 6, 7
293.	*Euplagia quadripunctaria* (Poda, 1761)	1, 3, 4
294.	*Grammodes stolida* (Fabricius, 1775)	5
295.	*Hypena lividalis* (Hübner, 1796)	2
296.	*Hypena proboscidalis* (Linnaeus, 1758)	5
297.	*Laspeyria flexula* (Denis & Schiffermüller, 1775)	1, 3, 5
298.	*Lithosia quadra* (Linnaeus, 1758)	1, 3, 5
299.	*Lygephila craccae* (Denis & Schiffermüller, 1775)	1, 3, 4, 5, 7
300.	*Lymantria dispar* (Linnaeus, 1758)	1, 3, 6, 7
301.	*Metachrostis dardouini* (Boisduval, 1840)	1

	Genus and species	Locality
302.	*Metachrostis velox* (Hübner, 1813)	1, 3, 4, 5, 6, 7
303.	*Minucia lunaris* (Denis & Schiffermüller, 1775)	3, 7
304.	*Ocneria rubea* (Denis & Schiffermüller, 1775)	1, 3, 4, 5, 6, 7
305.	*Odice suava* (Hübner, 1813)	4, 5, 6
306.	*Ophiusa tirhaca* (Cramer, 1773)	6
307.	*Pechipogo plumigeralis* Hübner, 1825	1, 3, 4, 5, 7
308.	*Phragmatobia fuliginosa* (Linnaeus, 1758)	1, 3, 5, 6, 7
309.	*Polypogon tentacularia* (Linnaeus, 1758)	5
310.	*Rhyparia purpurata* (Linnaeus, 1758)	7
311.	*Rivula sericealis* (Scopoli, 1763)	2
312.	*Schrankia costaestrigalis* (Stephens, 1834)	3, 6
313.	*Spilosoma lubricipeda* (Linnaeus, 1758)	5
314.	*Zebeeba falsalis* (Herrich-Schäffer, 1839)	1, 2, 3, 4, 5, 6, 7
	Euteliidae	
315.	*Eutelia adulatrix* (Hübner, 1813)	1, 2, 3, 4, 5, 6, 7
	Noctuidae	
316.	*Abrostola asclepiadis* (Denis & Schiffermüller, 1775)*	5
317.	*Acontia lucida* (Hufnagel, 1766)	1, 2, 3, 5
318.	*Acontia trabealis* (Scopoli, 1763)	1, 2, 3, 5, 6
319.	*Acronicta psi* (Linnaeus, 1758)*	3, 5, 6
320.	*Acronicta rumicis* (Linnaeus, 1758)	1, 3, 5, 6
321.	*Aedia leucomelas* (Linnaeus, 1758)	1, 2, 3, 5
322.	*Agrochola circellaris* (Hufnagel, 1766)	5
323.	*Agrochola lychnidis* (Denis & Schiffermüller, 1775)	1, 3, 5
324.	*Agrotis bigramma* (Esper, 1790)	3
325.	*Agrotis exclamationis* (Linnaeus, 1758)	2, 5
326.	*Agrotis ipsilon* (Hufnagel, 1766)	1, 3, 4, 5, 6, 7
327.	*Agrotis puta* (Hübner, 1803)	1, 2, 3, 4, 5, 6, 7
328.	*Agrotis segetum* (Denis & Schiffermüller, 1775)	2, 3, 4, 5, 6
329.	*Allophyes oxyacanthae* (Linnaeus, 1758)	1, 4, 5
330.	*Ammoconia caecimacula* (Denis & Schiffermüller, 1775)	5
331.	*Ammoconia senex* (Geyer, 1828)	5
332.	*Anarta trifolii* (Hufnagel, 1766)	1, 2, 3, 4, 5, 7

	Genus and species	Locality
333.	*Apamea monoglypha* (Hufnagel, 1766)	2
334.	*Aporophyla australis* (Boisduval, 1829)	3, 4, 5, 6
335.	*Aporophyla canescens* (Duponchel, 1826)	3, 5, 6
336.	*Aporophyla nigra* (Haworth, 1809)	3, 5, 6
337.	*Athetis hospes* (Freyer, 1831)	3, 4, 5
338.	*Autographa gamma* (Linnaeus, 1758)	1, 2, 3, 4, 5, 6, 7
339.	*Axylia putris* (Linnaeus, 1761)	3
340.	*Calophasia lunula* (Hufnagel, 1766)	3
341.	*Calophasia platyptera* (Esper, 1788)*	5
342.	*Caradrina clavipalpis* (Scopoli, 1763)*	2
343.	*Caradrina flavirena* Guenée, 1852*	3
344.	*Caradrina selini* Boisduval, 1840*	5
345.	*Caradrina terrea* Freyer, 1840*	5
346.	*Cerastis rubricosa* (Denis & Schiffermüller, 1775)	3, 4, 7
347.	*Charanyca trigrammica* (Hufnagel, 1766)	5
348.	*Chloantha hyperici* (Denis & Schiffermüller, 1775)	1, 2, 3, 5, 6
349.	*Chrysodeixis chalcites* (Esper, 1789)	1
350.	*Cleoceris scoriacea* (Esper, 1789)	7
351.	*Conisania luteago* (Denis & Schiffermüller, 1775)	1, 3, 4, 5
352.	*Conistra erythrocephala* (Denis & Schiffermüller, 1775)	3
353.	*Conistra rubiginea* (Denis & Schiffermüller, 1775)	1
354.	*Conistra vaccinii* (Linnaeus, 1761)	1, 2
355.	*Cosmia affinis* (Linnaeus, 1767)	2
356.	*Craniophora ligustri* (Denis & Schiffermüller, 1775)	1, 3, 4, 5, 6, 7
357.	*Cryphia algae* (Fabricius, 1775)*	1, 2, 3
358.	*Cryphia ochsi* (Boursin, 1940)*	1, 2, 3, 5, 6
359.	*Deltote pygarga* (Hufnagel, 1766)	6
360.	*Diloba caeruleocephala* (Linnaeus, 1758)	5
361.	*Dryobota labecula* (Esper, 1788)	5
362.	*Dryobotodes carbonis* Wagner, 1931*	5
363.	*Dryobotodes eremita* (Fabricius, 1775)?	3, 5
364.	*Dryobotodes monochroma* (Esper, 1790)	4, 5, 7
365.	*Dryobotodes tenebrosa* (Esper, 1789)	4, 5, 6

	Genus and species	Locality
366.	*Dypterygia scabriuscula* (Linnaeus, 1758)	1
367.	*Egira conspicillaris* (Linnaeus, 1758)	3
368.	*Emmelia trabealis* (Scopoli, 1763)	2
369.	*Episema glaucina* (Esper, 1789)	3, 4, 5, 6
370.	*Euxoa temera* (Hübner, 1808)	1, 5
371.	*Griposia aprilina* (Linnaeus, 1758)	5
372.	*Hadena compta* (Denis & Schiffermüller, 1775)	3, 5, 7
373.	*Hadena confusa* (Hufnagel, 1766)	6
374.	*Hadena perplexa* (Denis & Schiffermüller, 1775)	1, 3, 4, 5
375.	*Hecatera bicolorata* (Hufnagel, 1766)	3, 5
376.	*Helicoverpa armigera* (Hübner, 1808)	2, 5
377.	*Heliothis peltigera* (Denis & Schiffermüller, 1775)	1, 4, 5
378.	*Heliothis viriplaca* (Hufnagel, 1766)	1, 3, 4, 5, 6
379.	*Hoplodrina ambigua* (Denis & Schiffermüller, 1775)	2
380.	*Hoplodrina blanda* (Denis & Schiffermüller, 1775)	3, 6
381.	*Jodia croceago* (Denis & Schiffermüller, 1775)	3
382.	*Lacanobia oleracea* (Linnaeus, 1758)	3, 4, 6
383.	*Leucania putrescens* (Hübner, 1824)	1, 2, 3, 4, 5, 6, 7
384.	*Lithophane lapidea* (Hübner, 1808)	1, 3, 5, 6
385.	*Luperina dumerilii* (Duponchel, 1826)	1, 2, 3, 4, 5, 7
386.	*Mamestra brassicae* (Linnaeus, 1758)	3, 5, 6
387.	*Mesapamea secalella* Remm, 1983*	2
388.	*Mesapamea secalis* (Linnaeus, 1758)*	3, 4, 5, 6
389.	*Mesoligia furuncula* (Denis & Schiffermüller, 1775)	2, 3, 6
390.	*Mniotype solieri* (Boisduval, 1829)	2, 3, 4
391.	*Mythimna albipuncta* (Denis & Schiffermüller, 1775)	5
392.	*Mythimna ferrago* (Fabricius, 1787)	1, 2, 3, 4, 5, 7
393.	*Mythimna l-album* (Linnaeus, 1767)	3, 4, 5
394.	*Mythimna riparia* (Rambur, 1829)*	1, 3, 4
395.	*Mythimna sicula* (Treitschke, 1835)*	1, 2, 3, 4, 5, 6, 7
396.	*Mythimna unipuncta* (Haworth, 1809)	2, 3, 5
397.	*Mythimna vitellina* (Hübner, 1808)	1, 3, 4, 5, 6, 7
398.	*Noctua comes* Hübner, 1813	1, 3, 4, 5, 6, 7
399.	*Noctua fimbriata* (Schreber, 1759)*	1, 3, 4, 5, 6, 7
400.	*Noctua interjecta* Hübner, 1803	1, 2, 3, 4, 5, 6
401.	*Noctua janthina* Denis & Schiffermüller, 1775*	1, 3, 4, 5, 6, 7
402.	*Noctua pronuba* (Linnaeus, 1758)	1, 3, 4, 5, 6, 7
403.	*Noctua tirrenica* Biebinger, Speidel & Hanigk, 1983*	2, 4, 6
404.	*Nyctobrya amasina* Draudt, 1931*	3, 5, 6
405.	*Ochropleura leucogaster* (Freyer, 1831)	1, 2, 5
406.	*Ochropleura plecta* (Linnaeus, 1761)	3
407.	*Orthosia cerasi* (Fabricius, 1775)	1
408.	*Orthosia cruda* (Denis & Schiffermüller, 1775)	1, 3
409.	*Orthosia gothica* (Linnaeus, 1758)	4, 7
410.	*Panolis flammea* (Denis & Schiffermüller, 1775)	1
411.	*Peridroma saucia* (Hübner, 1808)	1, 5
412.	*Perigrapha rorida* Frivaldszky, 1835	6
413.	*Phlogophora meticulosa* (Linnaeus, 1758)	2, 3, 4, 5, 6
414.	*Phyllophila obliterata* (Rambur, 1833)	5
415.	*Polymixis serpentina* (Treitschke, 1825)	3, 4, 5, 6, 7
416.	*Polyphaenis sericata* (Esper, 1787)	1, 3, 4, 6
417.	*Rhizedra lutosa* (Hübner, 1803)	7
418.	*Sesamia cretica* Lederer, 1857	3
419.	*Sideridis rivularis* (Fabricius, 1775)	1
420.	*Simyra albovenosa* (Goeze, 1781)	3, 5
421.	*Spodoptera exigua* (Hübner, 1808)	1, 2, 3, 5, 7
422.	*Thalpophila matura* (Hufnagel, 1766)	1, 3, 4, 5, 6, 7
423.	*Trichoplusia ni* (Hübner, 1803)	2, 3, 7
424.	*Trigonophora flammea* (Esper, 1785)	5
425.	*Tyta luctuosa* (Denis & Schiffermüller, 1775)	1, 2, 3, 4, 5, 6
426.	*Valeria oleagina* (Denis & Schiffermüller, 1775)	1, 3, 4, 7
427.	*Xanthia gilvago* (Denis & Schiffermüller, 1775)	5
428.	*Xanthia ruticilla* (Esper, 1791)	1, 3, 4, 5, 6, 7
429.	*Xanthodes albago* (Fabricius, 1794)	2
430.	*Xestia castanea* (Esper, 1798)	3, 5
431.	*Xestia c-nigrum* (Linnaeus, 1758)	1, 2, 3, 4, 5, 6, 7

	Genus and species	**Locality**
432.	*Xestia xanthographa* (Denis & Schiffermüller, 1775)	1, 3, 5, 7
433.	*Xylocampa areola* (Esper, 1789)	4
	Nolidae	
434.	*Meganola albula* (Denis & Schiffermüller, 1775)	3, 5
435.	*Meganola strigula* (Denis & Schiffermüller, 1775)	1
436.	*Nola aerugula* (Hübner, 1793)	3
437.	*Nola chlamitulalis* (Hübner, 1813)*	3, 6
438.	*Nycteola asiatica* (Krulikovsky, 1904)*	3, 6
439.	*Nycteola columbana* (Turner, 1925)*	1, 3, 7
440.	*Nycteola siculana* (Fuchs, 1899)*	3
	Notodontidae	
441.	*Dicranura ulmi* (Denis & Schiffermüller, 1775)	6
442.	*Drymonia ruficornis* (Hufnagel, 1766)	3
443.	*Harpyia milhauseri* (Fabricius, 1775)	1, 3, 5
444.	*Peridea anceps* (Goeze, 1781)	3
445.	*Spatalia argentina* (Denis & Schiffermüller, 1775)	1, 3, 5
446.	*Thaumetopoea processionea* (Linnaeus, 1758)	1, 3, 5, 6, 7

RAZNOLIKOST NOČNIH METULJEV (LEPIDOPTERA: HETEROCERA) POMEMBNE POKRAJINE DONJI KAMENJAK IN MEDULINSKI ARHIPELAG, ISTRA, HRVAŠKA

Toni KOREN
Association Hyla, Zagreb, Croatia, Association Hyla, Zagreb, Croatia
e-mail: toni.koren@hhdhyla.hr

POVZETEK

V letu 2021 je bila v enoletnem študijskem obdobju raziskana pestrost nočnih metuljev Pomembne pokrajine Donji Kamenjak in medulinski arhipelag. Skupaj s podatki, zbranimi na več terenskih izletih v preteklih letih, je bilo na območju doslej zabeleženih 446 vrst nočnih metuljev. Številne zabeležene vrste spadajo med redko zabeležene vrste nočnih metuljev na Hrvaškem, nekatere pa predstavljajo šele drugo ali tretjo najdbo za državo. Ena vrsta, Eupithecia ultimaria *Boisduval, 1840, je prvič zabeležena na območju Hrvaške. Ugotovljene so bile tri glavne nevarnosti za pestrost nočnih metuljev, naravno nasledstvo zaradi pomanjkanja redne paše, obsežna mreža poti in cest, ki vodijo do drobljenja habitata ter visoka obremenitev z vozili v poletnih mesecih, ki povzroča dvig karbonatnega prahu od makadamskih cest na okoliških traviščih in rastlinju.*

Ključne besede: kraški travniki, makija, favnistika, svetlobne pasti, Natura 2000

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OCENE IN POROČILA

RECENSIONI E RELAZIONI

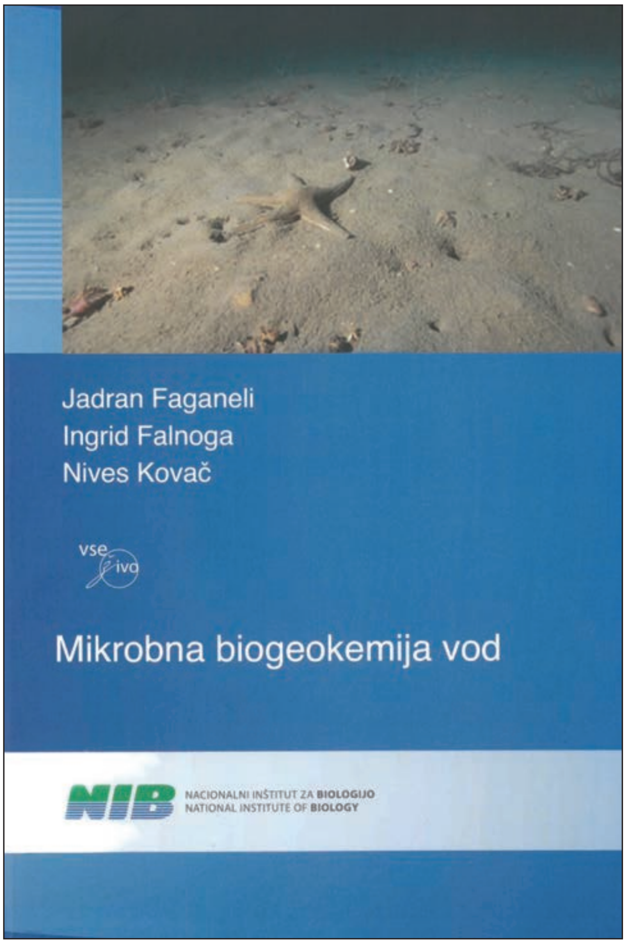
REVIEWS AND REPORTS

OCENE IN POROČILA, 263–264

Recenzija knjige:
MIKROBNA BIOGEOKEMIJA VOD

Avtorji: Jadran Faganeli, Ingrid Falnoga in Nives Kovač
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Biogeokemijski procesi oblikujejo naš planet. Vse večja onesnaženost okolja na lokalnem in globalnem nivoju, prekomerna izraba naravnih virov in klimatske spremembe so pereči problemi današnjega časa, zahtevajo rešitve in s tem tudi znanje biogeokemijskih procesov. Ta razkrije pričujoča knjiga avtorjev J. Faganelija, I. Falnoge in N. Kovač »*Mikrobna biogeokemija vod*«, ki prinaša poglobljen uvid v biogeokemijska dogajanja v vodnih okoljih, temelji na bogatih raziskovalnih izkušnjah avtorjev ter poveže njihove raziskave vodnih ekosistemov v Sloveniji z rezultati drugih strokovnjakov s tega področja. Vsebuje 12 poglavij z opisom kroženja pomembnih elementov v različnih rezervoarjih od atmosfere, hidrosfere in sedimentov do biogeokemije in geomikrobiologije fosilnih goriv. Knjiga je prva tovrstna v Sloveniji, obširno delo, ki bralcu omogoča, da si pridobi zelo široko zanje s tega področja ter še posebej naslavlja raznovrsten nabor metod, ki so jih avtorji uporabili v raziskavah vodnih okoljih, kot sta Tržaški zaliv in Blejsko jezero. V uvodnem delu na zelo zanimiv način in z znanstveno podkrepljenimi razlagami predstavi nastanek vesolja, osončja, Zemlje, za življenje pomembnih kemijskih elementov in nastanek življenja na našem planetu. Poglobljeno in zanimivo je predstavljena atmosfera in aktualen problem globalnih klimatskih sprememb. To poglavje nato nadgradi obširna in poglobljena razlaga dinamičnih kemijskih in bioloških procesov v hidrosferi s poudarkom na oceanih in obalnem morju, rekah, jezerih, močvirjih in sedimentih. Avtorji uspešno povežejo kemijske uvide z biološkimi, predvsem mikrobnimi, procesi in tako bralcu na prijazen in poglobljen način razkrijejo principe in dinamiko biogeokemijskega kroženja pomembnih elementov C, N, S, P, Si, Se in As. Še posebej poglobljeno se bralec spozna s kroženjem Fe, Mn in Hg, saj je kroženje kovin povezano z raziskovalnimi izkušnjami avtorjev. Pomembna je predstavitev uporabe stabilnih izotopov lahkih in težjih elementov, ki nam pomagajo razumeti procese, transport in izvor elementov v okolju. Izotopski prstni odtis, ki nastane pri različnih biogeokemijskih procesih, se prenaša v končne produkte ter s tem omogoča sledenje izvorov in poti pretvorb raziskovanih elementov. Najbolj izrazite frakcionacije so opazne v mikrobnih procesih. Z razvojem visoko ločljivih analiznih metod, kot je multikolektorska masna spektrometrija z induktivno sklopljeno plazmo (MC-ICPMS), se je pojavilo veliko študij posvečenih izotopski frakcionaciji elementov, kot so Fe, Cd, Se, in Hg. Slednja je v zadnjih dveh desetletjih bistveno poglobila razumevanje njihovih biogeokemijskih pretvorb. Zadnje poglavje je namenjeno pregledu metod, ki se najbolj uporabljajo pri študiju mikrobnih biogeokemijskih procesov v vodah. Na koncu poglavij je dodana literatura za nadaljnje branje. V knjigo so vključeni številni rezultati lastnega raziskovalnega dela s področja biogeokemije vod, kar ji daje unikaten pečat in prvič prinaša poglobljene uvide v biogeokemijske procese v različnih vodnih okoljih v Sloveniji, v Severnem Jadranu, tudi Sečoveljskih solinah in Tržaškem zaliva ter Blejskem jezeru. Pomembna prednost knjige je interdisciplinarnost ter povezovanje teorije s prakso, kar ji dviguje uporabno vrednost in predstavlja pomembno zakladnico znanj.



Avtorji delijo z bralci svoje znanje na svež način, povežejo že znano z novimi uvidi lastnih raziskav in tako ustvarijo in ponudijo prvo znanstveno monografija te vrste v slovenskem jeziku. Ta bo dober vir znanj za strokovnjake in raziskovalce, ki se ukvarjajo z okoljskimi problemi in pomembna za univerzitetne pedagoge in študente, ki si želijo poglobljenega znanja iz biogeokemije. Avtorji so mednarodno uveljavljeni raziskovalci z dobrimi referencami in bogatimi izkušnjami na področju okoljskih raziskav severnega Jadrana ter obširnim znanstvenim opusom. Knjiga, ki izhaja iz odličnega poznavanja varstva okolja in bogatih raziskovalnih izkušenj avtorjev na področju biogeokemije vod, je kvalitetno delo, ki prinaša sveže uvide biogeokemika v danes zelo aktualne probleme v vodnih okoljih. Knjiga je opremljena s številnimi slikami in grafi, ki so plod raziskovalnega dela avtorjev, kar obogati pričujoče delo z unikatnim pečatom.

Ines Mandić Mulec
Biotehniška fakulteta, Univerza v Ljubljani

Nives Ogrinc
Institut Jožef Stefan

KAZALO K SLIKAM NA OVITKU

SLIKA NA NASLOVNICI: Kavljezobo mureno (*Enchelycore anatina*) so v zadnjem desetletju potrdili v različnih predelih Sredozemskega morja. Naseljuje skalnato dno s številnimi rovi in votlinami, iz katerih opazuje dogajanje v okolici. (Foto: B. Furlan)

Sl. 1: Peščeni morski pes (*Carcharhinus obscurus*) se v zadnjih desetletjih pogosteje pojavlja v Sredozemskem morju. Iz turških morij poročajo o pojavljanju mladih primerkov te vrste. (Foto: B. Furlan).

Sl. 2: Progasti bradač (*Mullus surmuletus*) je pogosta obrežna riba, ki se pojavlja povsod v Sredozemskem morju. Ponekod, na primer v tunizijskih vodah, ima ta pridnena riba velik komercialni pomen. (Foto: B. Furlan)

Sl. 3: Na navadnega špara (*Diplodus annularis*), enega izmed štirih predstavnikov iz rodu *Diplodus*, naletimo praktično povsod v Sredozemskem morju. Za poznavalce je cenjena in okusna riba.

Sl. 4: Mangrovski rdeči hlastač (*Lutjanus argentimaculatus*) je velika riba, ki zraste do 80 cm v dolžino, in je splošno razširjena v Indo-zahodnem Pacifiku. Pred kratkim so o tem lesepskem migrantu poročali z Malteških otokov. (Foto: B. Furlan)

Sl. 5: Marmorirani morski kunec (*Siganus rivulatus*) je invazivna lesepska selivka, ki so jo v Sredozemskem morju prvič potrdili že leta 1927. Danes se redno pojavlja predvsem v vzhodnem delu Sredozemskega morja. (Foto: B. Furlan)

Sl. 6: Morski travniki kolenčaste cimodoceje (*Cymodocea nodosa*) so produktivna življenjska okolja v Jadranskem morju, ki nudijo bivalne niše, hrano in zavetje pred plenilci mnogim pomembnim organizmom v lagunskih in morskih ekosistemih, poleg tega pa imajo velik pomen za dobrobit človeka. (Foto: L. Lipej)

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FRONT COVER: The fangtoothed moray eel (*Enchelycore anatina*) has been confirmed in various parts of the Mediterranean Sea over the last decade. It inhabits rocky bottoms with numerous burrows and cavities from which it observes events in its surroundings. (Photo: B. Furlan)

Fig. 1: Over the recent decades, the dusky shark (*Carcharhinus obscurus*) has become more common in the Mediterranean. Young specimens of this species have been reported in Turkish seas. (Photo: B. Furlan)

Fig. 2: The striped red mullet (*Mullus surmuletus*) is a common coastal fish species occurring throughout the Mediterranean. In some places, such as Tunisian waters, this demersal fish has a great commercial importance. (Photo: B. Furlan)

Fig. 3: The two-banded seabream (*Diplodus annularis*), one of the four representatives of the genus *Diplodus*, is found virtually everywhere in the Mediterranean. For connoisseurs, it is a prized and delicious fish. (Photo: B. Furlan).

Fig. 4: The mangrove red snapper (*Lutjanus argentimaculatus*) is a large fish with a common length of up to 80 cm and a wide Indo-West Pacific distribution. Recently, this Lessepsian migrant has been reported from the Maltese Islands. (Photo: B. Furlan)

Fig. 5: The marbled spinefoot (*Siganus rivulatus*) is an invasive Lessepsian migrant, first confirmed in the Mediterranean as early as 1927. Today, its regular appearance is mainly circumscribed to the eastern Mediterranean. (Photo: B. Furlan)

Fig. 6: The *Cymodocea nodosa* seagrass meadows are among the most productive ecosystems in the Adriatic Sea, providing habitats, food and refuges for numerous organisms in lagoon and marine ecosystems, and are of great importance for human well-being as well. (Photo: L. Lipej)

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